GUNSHOT WOUNDS

C. G. SPENCER

OXFORD MEDICAL PUBLICATIONS

Jb* 1. 56.

R39658

Digitized by the Internet Archive
in 2015

https://archive.org/details/b21905927

OXFORD MEDICAL PUBLICATIONS

GUNSHOT WOUNDS

BY

C. G. SPENCER

M.B., LOND., F.R.C.S., ENG.

MAJOR, ROYAL ARMY MEDICAL CORPS; PROFESSOR OF MILITARY SURGERY, ROYAL ARMY MEDICAL COLLEGE, LONDON

ROYAL COLLEGE OF PHYSICIANS, EDINR
LIBRARY

HENRY FROWDE — OXFORD UNIVERSITY PRESS
HODDER & STOUGHTON — WARWICK SQUARE, E.C.

1908

PREFACE

This manual is intended to meet the need, which undoubtedly exists, of a short introduction to the subject with which it deals, while it does not pretend to compete in any way with the larger works on the subject. It is based on lectures given during the past three years at the Royal Army Medical College.

No claim is made to originality, and free use has been made of the writings of Surgeon-General Stevenson, Mr. Makins, and the several authors of the official *Report* on the Surgical Cases noted in the South African War.

Considerations of space have prevented the inclusion of many illustrative cases, but references are given to many cases of interest in the works above referred to.

The author's thanks are due to Mr. G. H. Makins, C.B., for his kind permission to use a number of the illustrations from his *Surgical Experiences in*

South Africa, to Surgeon-General W. F. Stevenson, C.B., K.H.S., for permission to use four illustrations from his *Wounds in War*, to Major M. P. Holt, D.S.O., R.A.M.C., for much assistance and many helpful suggestions, and to Captain H. Simson, R.A.M.C., for assistance in correcting the proofs.

It is hoped that the book may prove of use to medical officers of the Services, and to others interested in the subject.

C. G. S.

May, 1908.

CONTENTS

CHAPTER I

INTRODUCTION—MECHANICS OF PROJECTILES

CHAPTER II

GENERAL CHARACTERS AND EFFECTS OF GUNSHOT WOUNDS

CHAPTER III

WOUNDS OF VESSELS

CHAPTER IV

INJURIES OF NERVES

CHAPTER V

FRACTURES

CHAPTER VI

WOUNDS OF JOINTS

CHAPTER VII

WOUNDS OF THE HEAD

CHAPTER VIII

WOUNDS OF THE SPINE

CHAPTER IX

WOUNDS OF THE NECK

CHAPTER X

WOUNDS OF THE CHEST

CHAPTER XI

WOUNDS OF THE ABDOMEN

LIST OF ILLUSTRATIONS

Several of these are reproduced from the *Report on the Surgical Cases noted in the South African War*, 1899–1902, by permission of the Controller of H.M Stationery Office.

FIGURES IN TEXT

CHAPTER I

INTRODUCTION

Gunshot wounds form a special class of injuries, rarely met with except in war. Those seen in civil practice, whether suicidal, homicidal, or accidental, are not usually inflicted by military rifles, but by shot-guns, revolvers, or pistols; the revolvers are not often such powerful weapons as the service pattern. When rifles have been used under such circumstances it has generally been at extremely close quarters, as in suicidal wounds; the effects are then complicated by the direct action of the blast of the explosive, and the general results differ greatly from what are usually met with in warfare.

To be prepared to treat wounds in time of war, it is necessary to study the nature of the injuries that will be met with, the means by which they are produced, and particularly the circumstances under which treatment will have to be carried out. Usually the ordinary rules of surgery apply to the treatment

of gunshot wounds, but the conditions of active service necessarily affect the treatment to an extent not appreciated in civil life, many of the procedures and methods most useful under peace conditions being either quite impracticable or dangerous in the very different circumstances under which the surgeon works in war.

What these circumstances are will be described in detail later; for the present it is sufficient to emphasise the fact that in war the surgeon works under difficulties, and that he must be prepared to do without many of the conveniences and not a few of the essentials of a modern hospital. Surgery in the field is, in fact, surgery *in arduis*, as the motto of the Royal Army Medical Corps reminds us, and the surgeon must do the best he can with the limited resources at his disposal. He will be wise, therefore, to study in time of peace to adapt his methods and technique to the requirements of war. It is not meant that he should refuse to avail himself of every convenience that he can obtain for the better performance of his duties, but he must learn to regard such things as luxuries, not as necessaries, and must be prepared to work, if need be, with the simplest means.

Although for special purposes special instruments are useful and sometimes indispensable, the great majority of operations can be done with the simplest armamentarium, and very many of the ingenious tools that fill the instrument makers' catalogues and the instrument cupboards of our hospitals are altogether superfluous, or are needed only on very rare occasions. Ligature and suture materials, too, need be only of the simplest description, as long as they can be boiled and are sufficiently strong. For unabsorbable sutures plain linen thread is as good as any of the specially prepared materials on the market. Absorbable ligatures and sutures should always be used in septic wounds, as they do not keep sinuses open as silk and other unabsorbable materials do, and for these catgut prepared by the iodine method is most suitable—it is cheap, easily prepared, and can be carried dry. Although only silk ligatures were used on both sides in the Russo-Japanese war, and the Russian surgeons condemned animal ligatures for field use,[1] there can be no doubt of the disadvantages of silk and the superiority of catgut in septic wounds.

[1] Hoff, *Journal of the Association of Military Surgeons*, August, 1906.

For dressing materials plain dry gauze and wool, ready sterilised, meet all requirements, and serve also for swabs.

For sterilising the surgeon will often have to depend on simple boiling, as special sterilising apparatus is difficult to carry in the field. Boiling will, of course, be the method used for instruments; towels and swabs may also be boiled and wrung out in a boiled towel for use. Strong antiseptics are to be avoided, except for the patient's skin and the surgeon's hands. On no account should strong antiseptic lotions be used in wounds, even if septic; they do little harm to the micro-organisms and much to the tissues. The worst thing that can be put into a wound is a dirty hand, and the next worst is a strong antiseptic.

In the matter of technique, the surgeon should learn to trust no hands but his own, and to regard even those with suspicion. He should practise keeping his hands out of the wound as much as possible at operations, and should never let them be soiled when dressing septic cases. At operations he should learn to do without assistance, or with only unskilled assistance, and he will find that performing one or two common operations, such as

radical cure of hernia, without assistance, will teach him much that will be of use to him when he is called on to deal with an urgent case single-handed in the field, and will give him confidence in his ability to work unaided.

Besides the foregoing purely technical considerations, there are others that, though less important, are well worth the attention of every military surgeon. It is a great advantage to a surgeon to have some facility in the use of tools, to be able to design and make his own splints, and to improvise apparatus from ordinary materials. He should also be able to keep his tools and instruments in order, sharpen knives, tighten loose joints of scissors and forceps, and adjust minor defects in other apparatus. Different individuals vary greatly in mechanical ability and aptitude, but every man with any degree of mechanical ability should cultivate it, and those who are without it are scarcely likely to make useful surgeons. A surgeon, and especially a military surgeon, ought to be as much as possible a man "with the use of his hands."

As to the results to be expected from surgical work under field conditions, everything depends on the zeal and energy with which the difficulties are faced.

To expect bad results is the surest way to get them, and taking a pessimistic view is certain to lead to slackness and carelessness in technique, particularly as regards aseptic precautions, thus bringing about the very disaster that is feared. Though it may seem that under such conditions it is impossible to attain the high average of aseptic results commonly experienced in civil practice, yet it is only by all working for the best possible results that progress in this respect can be made, and the experience of recent wars leads us to hope for still better results in the future.

MECHANICS OF PROJECTILES

Under this heading only those facts which are of importance to the surgeon as affecting the power of the bullet to inflict injury need be considered.

A bullet or other projectile from a rifled weapon has two motions, one of translation along its long axis, and the other of rotation about that axis. The first is due to the momentum imparted by the explosion of the charge, the second to the spiral grooves of the rifling of the barrel.

A bullet after leaving the muzzle of the rifle is acted on by the following forces [1] :—

(1) The blast of gas from the muzzle.

(2) The resistance of the air.

(3) Gravity.

4) Wind.

(5) The spin of the bullet causing "drift."

Of these, only **gravity** and the **resistance of the air** need further consideration. The blast of gas from the muzzle acts for a very short time, and tends to increase the velocity of the bullet. The effect of wind in deflecting the bullet from its path is of importance to the marksman, not to the surgeon; and the same may be said of the deflection due to "drift" (for an explanation of which the reader is referred to the official *Text-book of Small Arms*, 1904, p. 242).

Gravity acting on a body free to move produces an acceleration of (in round numbers) 32 feet per second in a vertical direction. The distance a body falls in a given time under the influence of gravity is found from the formula $h=\frac{1}{2}gt^2$, where h is the distance fallen in feet, g the acceleration due to gravity (32 feet per second), and t the time in

[1] *Text-book of Small Arms,* 1904, p. 234.

seconds. Hence it is evident that a falling body travels 16 feet in a vertical direction in the first second, 64 feet in two seconds, 144 feet in three seconds, and so on. A bullet fired from the point O (Fig. 1), in the direction OC, would, if we suppose neither gravity nor the resistance of the air to exist, continue to travel in the same straight line with uniform velocity, reaching the point A at the end of one second, B at the end of two seconds, and C at the end of three seconds, the distances OA, AB, BC being equal. But owing to the action of gravity the bullet would fall 16 feet in the first second, and so would reach the point D, 16 feet below A. In the first two seconds it would fall 64 feet, and reach the point E, 64 feet below B, and in the first three seconds it would fall 144 feet, and reach the point F, 144 feet below C.

So much would be due to gravity alone, if the bullet were travelling in a vacuum. The **resistance of the air** causes the bullet to lose its velocity rapidly, so that the distance travelled in each successive second becomes less and less. Thus in Fig. 1, the bullet would travel only the distances O*a*, *ab*, *bc*, in the first, second, and third seconds, instead of the distances OA, AB, BC, and would

actually reach the points *d*, *e*, *f*; 16, 64, and 144 feet below *a*, *b*, and *c*; and the path or **trajectory** would be not the parabola O D E F, but the more sharply curved line O *d e f*, the curvature of which increases as the distance from O increases.

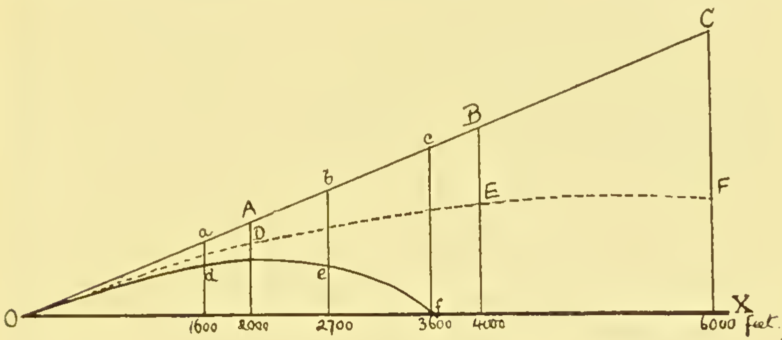


FIG. 1.—Tracjetory in vacuo (dotted) and in air.

This diagram represents roughly the trajectory of the Lee-Enfield bullet over a range of 1,200 yards (3,600 feet). The bullet has an initial velocity of about 2,000 feet per second, and travels approximately 1,600, 2,700, and 3,600 feet in 1, 2, and 3 seconds respectively.

The horizontal scale is 1/24,000 (1 inch = 2,000 feet), and the vertical scale is 1/2,400 (1 inch = 200 feet). All the vertical measurements are therefore represented on a scale ten times larger than the horizontal measurements. The angle *COX* is actually so small (less than 2) that *OC* is nearly parallel to *OX*, and the difference between measurements along *OC* and along *OX* may be neglected.

OA, *AB*, and *BC* each = 2,000 feet. *Oa* = 1,600 feet, *ab* = 1,100 feet, and *bc* = 900 feet.

The great effect of the resistance of the air is strikingly shown.

The resistance of the air depends on—

(1) The velocity of the bullet. At velocities of less than 900 feet per second, and at velocities of over 1,300 feet per second, the resistance varies

as the square of the velocity. At velocities between 900 and 1,300 feet per second the resistance varies as higher powers of the velocity, being proportional to the sixth power for a certain interval between 1,000 and 1,100 feet per second.

(2) The cross-section area of the bullet.

(3) The shape of the head of the bullet. The more gradually the head of the bullet tapers, the less is the resistance. Taking the resistance to a

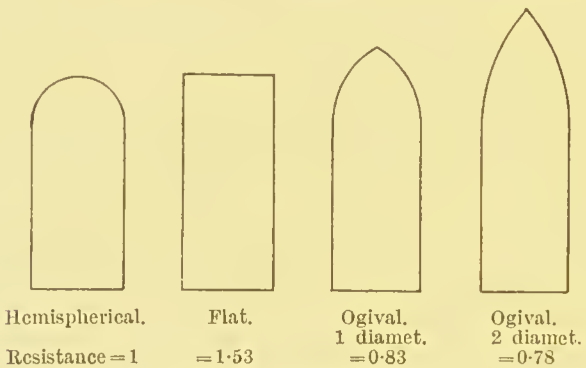


Fig. 2.—Shapes of Heads of Bullets.

bullet with a hemispherical head as unity, the resistance to a bullet of the same diameter with a flat head is 1·53, that to one with an ogival head of one diameter is 0·83, and that to one with an ogival head of two diameters is 0·78. (An ogival head of one diameter or of two diameters means that the radius of the curve forming the

head of the bullet is equal to one or to two diameters of the base of the bullet.)

(4) The density of the atmosphere, which varies with the temperature, the pressure, and the amount of moisture present.

(5) The steadiness of flight of the bullet also affects the resistance met with from the air. If the bullet, instead of rotating about its long axis, rotates about any other axis, it meets with increased resistance. The Lee-Enfield bullet begins to lose its steadiness of flight at about 1,000 yards from the firing point, and the nose and base of the bullet then begin to gyrate about the trajectory.

The power of a bullet to overcome the resistance of the air, upon which its ranging power depends, is expressed by the ratio of the weight of the bullet to its cross-section area. This fraction, $\frac{\text{weight}}{\text{cross-section area}}$, is called the **sectional density.** The cross-section area of a bullet with diameter d is $\frac{1}{4}\pi d^2$, and so the sectional density is $\frac{W}{\frac{1}{4}\pi d^2}$, but as $\frac{1}{4}\pi$ is the same for all bullets it may be neglected, and for the purpose of comparing different bullets the sectional

density is usually taken as $\frac{W}{d^2}$, that is, the ratio of the weight to the square of the diameter.

The **rotation** of a bullet about its long axis is necessary to keep it moving point foremost. But for the rotation imparted by the grooves of the rifling, an elongated bullet would spin over and over on its transverse axis, and would meet with much more resistance from the air, and have much less ranging power. As bullets have been made smaller and smaller, in order to keep up their weight and increase their sectional density they have been made longer, and that necessitates giving them a more rapid movement of rotation. Thus the Snider bullet makes one complete turn in 78 inches, the Martini-Henry bullet one turn in 22 inches, and the Lee-Enfield one turn in 10 inches.

Dangerous Zones.—As the trajectory of a bullet is a curve, at all except the shorter ranges some part of the bullet's course will be at such a height above the ground as to pass over the heads of men, whether mounted or on foot. As soon as the bullet descends within 8½ feet of the ground it would strike a mounted man, and this point is called the point of "first catch" for cavalry (*c*,

Fig. 3), and from this point to the end of the bullet's flight is the "dangerous zone" for cavalry. When the bullet descends within 6 feet of the ground it would strike a standing man, this is the point of first catch for infantry (*i*, Fig. 3), and the dangerous zone for infantry extends thence to the end of the bullet's flight.

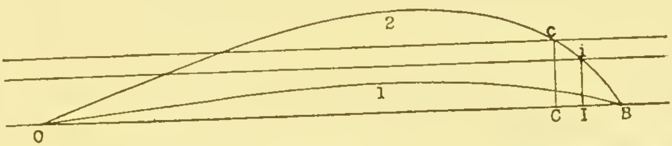


FIG. 3.—Comparison of the trajectories of the Lee-Enfield and Martini-Henry bullets at a range of 500 yards.

Horizontal scale = 1/7,200 (1 inch = 200 yards).
Vertical scale = 1/360 (1 inch = 30 feet).
Vertical measurements are represented on a scale twenty times larger than horizontal measurements.
The Lee-Enfield bullet follows the trajectory marked 1, its highest or "culminating" point is 3·9 feet above the ground line, and its "dangerous zone" extends over its whole course. The Martini-Henry bullet has the trajectory 2, its culminating point is 13·2 feet above the ground line, and as it descends it comes within 8½ feet of the ground at *c*, and within 6 feet at *i*, so that its "danger zone" for cavalry extends from *C* to *B*, and that for infantry from *I* to *B*

The less curved the trajectory, the longer the dangerous zones will be, and if the trajectory does not rise more than 6 feet from the ground at any point the dangerous zone for infantry will extend over the whole of the bullet's course. (Lee-Enfield at 500 yards, Fig. 3.) The flatness of the trajectory is most marked at short ranges, and depends on

the velocity of the bullet being high. Besides increasing the dangerous zone, flatness of the trajectory renders mistakes in estimating the range and in sighting less important, and the increased velocity gives the bullet greater power of inflicting injury. Long ranging power and flatness of tra-

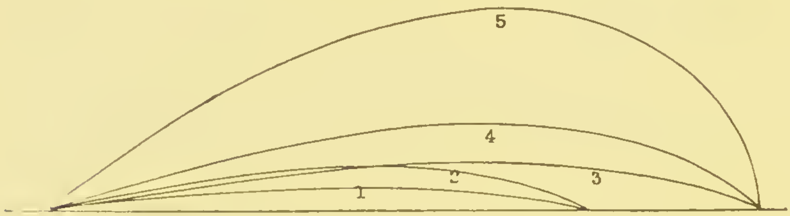


Fig. 4.

				Culm. point.
1.	Trajectory of Lee-Enfield	at 1,500	yards	. 81 feet
2.	" " Martini-Henry	"	"	. 178 "
3.	" " Lee-Enfield	2,000	"	. 194 "
4.	" " Martini-Henry	"	"	. 357 "
5.	" " Snider	"	"	. 866 "

Horizontal scale, 1/24,000 (1 inch = 2,000 feet).
Vertical scale, ·/12,000 (1 inch = 1,000 feet).
Vertical measurements are represented on twice as large a scale as horizontal measurements.

jectory are all-important in modern small arms, so the bullet must have great initial velocity and must retain its velocity as long as possible. The theoretical dangerous zones are greatly modified in actual warfare by inequalities of the ground, and by the fact that troops seldom stand up under fire. When troops are well protected by cover, as in trenches, high angle fire, the projectiles from which descend

nearly vertically, will be more effective against them than direct fire, and the advantages of flatness of trajectory disappear.

Wounding Power of Bullets.—The wounding effect of a bullet depends on [1]—

(1) Its *energy*, and

(2) *The facility with which it converts its energy into work* on striking.

The first factor, the energy, or power of doing work, is expressed by the formula $E = \frac{MV^2}{2}$, where E is the energy, M the mass of the bullet, and V the velocity in feet per second at the moment of striking. As the velocity, owing to the resistance of the air, diminishes rapidly the further the bullet travels, and as the energy is proportional to the square of the remaining velocity at any range, it follows that the energy is relatively very great at short ranges, and diminishes very rapidly as the range increases. The following table [2] of the velocity and energy of the Lee-Enfield bullet at various ranges illustrates this—

[1] *Text-book of Small Arms*, p. 145.

[2] *Text-book of Small Arms*, p. 251.

Range.	Velocity in feet per second.	Energy in foot-pounds.
At muzzle . . .	2,060	2,025
At 300 yards . .	1,518	1,098
,, 700 ,, . .	1,039	512
,, 1,000 ,, . .	889	379
,, 2,000 ,, . .	571	155
,, 3,000 ,, . .	369	65

This shows that at 300 yards the energy is little more than one-half the original energy, and at 700 yards little more than one-quarter.

The second factor that determines the wounding effect of a bullet, the facility with which it converts its energy into work, depends on—

(1) The cross-section area of the bullet. The larger the bullet the more work it has to do in cutting its way through the tissues. The effect of reducing the diameter of bullets is to reduce their wounding power.

(2) The liability of the bullet to "set up" or break up, that is, to increase its sectional area. A bullet that expands or "mushrooms" on striking will inflict a much more severe wound than one that does not become deformed. The small-bore bullet was believed when first it came into use to

be deficient in stopping power, that is, the wounds it inflicted were thought to be not severe enough to prevent a determined adversary charging home. For this reason various forms of bullet were devised which were intended to set up on impact and so inflict more severe wounds. As the use of these expanding bullets, often inaccurately spoken of as "explosive bullets," has been forbidden by the Hague Convention, they need not be discussed further. They are used only for sporting purposes.

(3) The resistance met with. This is of great importance in determining the amount of the bullet's energy that must be expended in overcoming it. If the resistance is sufficient to stop the bullet, all its energy will be expended. If the energy of the bullet is great and the resistance it meets with is small, only sufficient energy to overcome the resistance will be expended, and the bullet will pass on with comparatively little loss of energy.

In comparing different missiles — the small-bore bullet, the larger rifle bullets such as the Martini-Henry, shrapnel bullets, and fragments of shell—all the above conditions vary. Taking any

particular bullet, all of them are constant except the energy and the resistance met with. The energy, or power of doing damage, depends on the velocity, that is, on the range. The damage actually done depends largely on the resistance, and on the amount of energy required to overcome it. Thus at a short range a bullet striking a highly resistant tissue such as the shaft of a long bone will inflict very severe injury, while the same bullet striking the chest, and meeting with the very small resistance of the soft parts of the chest wall and the lung, will inflict comparatively trifling injury. At a long range the damage to the bone will be much less on account of the decreased energy of the bullet, while the damage to the chest and lung will be much the same as at the short range, the resistance requiring just the same expenditure of energy to overcome it, and the bullet still having energy enough to do so.

It must be admitted that in many wounds the amount of damage done cannot be so easily explained, but speaking generally the explanation given above applies to the great majority of gunshot wounds.

Weapons and Missiles.—The Lee-Enfield may

be taken as a typieal modern small-bore rifle. Its calibre is ·303 ineh (7·7 mm.) The rifling has five grooves, whieh make one turn to the left in 10 inehes. The bullet has a length of 1·25 ineh (31·75 mm.), and a diameter of ·311 ineh, (7·9 mm.). Its weight is 215 grains (13·9 grammes), and it has an ogival head of two diameters. It eonsists of a eore of lead, hardened by the addition of 2 per eent. of antimony, and an envelope of eupro-niekel, an alloy of four parts of eopper to one part of niekel, with a small quantity ($\frac{1}{2}$ p.e.) of iron. The reason for eovering the lead with an envelope of harder metal is that lead alone is too soft, a leaden bullet would not follow the grooves of the barrel, but its surfaee would be torn off by them and the neeessary rotation would not be imparted to it. The rifle is sighted to 2,800 yards (2,560 metres), and its extreme range is 3,740 yards (3,420 metres). The initial veloeity of the bullet is 2,060 feet (628 metres) per seeond.

The annexed table gives the ehief features of some of the prineipal small-bore rifles of other Powers for comparison.

MAGAZINE RIFLES OF SMALL

Country.	*Austria, Bulgaria & Greece.*	*Belgium.*	*Denmark.*	*Great Britain.*	*France.*	*Germany.*	*Holland.*
Designation and Date	Mannlicher, 1895	Mauser, 1889	Krag-Jorgensen, 1889	Short Lee-Enfield, 1903	Lebel, 1886	Mauser, 1898	Mannlicher, 1895
Magazine contains	5 cart.	5 cart.	5 cart.	10 cart.	8 cart.	5 cart.	5 cart.
Charger or Clip	Clip	Charger	Charger	Charger	No	Charger	Clip
Calibre of barrel	8 mm. ·315 in.	7·65 mm. ·301 in.	8 mm. ·315 in.	7·7 mm. ·303 in.	8 mm. ·315 in.	7·9 mm. ·311 in.	6·5 mm. ·256 in.
Rifling, number of grooves	4	4	6	5	4	4	4
1 turn in	9·842 in.	9·842 in.	11·811 in.	10 in.	9·45 in.	9·39 in.	7·874 in.
Direction of twist	To right	To right	To right	To left	To left	To right	To right
Sighted up to	2,600 paces, 2,132 yds.	2,000 m. 2,187 yds.	1,900 m. 2,078 yds.	2,560 m. 2,800 yds.	2,000 m. 2,187 yds.	2,000 m. 2,187 yds.	2,000 m. 2,187 yds.
Bullet, envelope of	Steel, lubricated	Cupro-nickel	Cupro-nickel	Cupro-nickel	Cupro-nickel	Steel, coated with cupro-nickel	Steel, coated with cupro-nickel
Length	1·24 in.	1·205 in.	1·187 in.	1·25 in.	1·221 in.	1·235 in.	1·23 in.
Diameter	·3228 in.	·31 in.	·323 in.	·311 in.	·3228 in.	·3189 in.	·2637 in.
Weight	244 gr.	219 gr.	237 gr.	215 gr.	231 gr.	227 gr.	162 gr.
Value of $\frac{W}{d^2}$	·334	·330	·325	·3205	·320	·322	·334
Muzzle velocity (f.s.)	2,034	2,034	1,968	2,060	2,073	2,093	2,433

Fuller details will be found in the *Text-Book of Small Arms*, 1904

CALIBRE OF THE DIFFERENT POWERS.

Italy.	*Japan.*	*Portugal.*	*Roumania.*	*Russia.*	*Spain.*	*Switzerland.*	*Turkey.*	*United States.*
Mannlicher-Carcano, 1891	Year '30, 1900	Kropatschek, 1886	Mannlicher, 1893	"3-line" Nagant, 1894	Mauser, 1896	Schmidt-Rubin, 1900	Mauser, 1893	Krag-Jorgensen, 1898
6 cart.	5 cart.	9 cart.	5 cart.	5 cart.	5 cart.	6 cart.	5 cart.	5 cart.
Clip	Charger	No	Clip	Charger	Charger	Charger	Charger	Charger
6·5 mm. ·256 in.	6·5 mm. ·256 in.	8 mm. ·315 in.	6·5 mm. ·256 in.	7·62 mm. ·3 in.	7 mm. ·276 in.	7·5 mm. ·295 in.	7·65 mm. ·301 in.	7·62 mm. ·3 in.
4	6	4	4	4	4	3	4	4
Increasing	7·875 in.	11 in.	7·874 in.	9·5 in.	8·68 in.	10·63 in.	10 in.	10 in.
To right	To right	To right	To right	To right	To right	To right	To right	To right
2,000 m. 2,187 yds.	2,000 m. 2,187 yds.	2,200 m. 2,406 yds.	2,000 m. 2,187yds.	2,700 paces 2,096 yds.	2,000 m. 2,187 yds.	1,200 m. 1,312 yds.	2,000 m. 2,187 yds.	1,645 m. 1,800 yds.
Cupro-nickel	Copper	Steel	Cupro-nickel	Cupro-nickel	Cupro-nickel	Steel, point only	Steel, coated with cupro-nickel	Cupro-nickel
1·182 in.	1·28 in.	1·279 in.	1·244 in.	1·194 in.	1·21 in.	1·18 in.	1·212 in.	1·26 in.
·266 in.	·26 in.	·3228 in.	·2637 in.	·308 in.	·2843 in.	·319 in.	·311 in.	·308 in.
163 gr.	162·9 gr.	248 gr.	162 gr.	214 gr.	172·8 gr.	212·5 gr.	211·3 gr.	219·5 gr.
·337	·337	·34	·334	·324	·313	·337	·325	·337
2,395	2,390	1,750	2,400	1,985	2,296	1,920	2,066	1,923

(Table IV, p. 312), from which the above particulars are taken.

As instances of the older types of rifle, the following particulars of the Martini-Henry and the Snider are given—

	Martini-Henry.	Snider.
Calibre . . .	·450 inch	·577 inch
Rifling . . .	1 turn to R. in 22″	1 turn to R. in 78″
Bullet	Hard lead, 480 gr.	Soft lead, 480 gr.
Initial velocity .	1,350 f.s.	1,240 f.s.

Experiments have recently been made with the object of increasing the initial veloeity of the bullet by reducing its weight and increasing the power of the eharge, and at the same time diminishing the resistance of the air to the bullet by making its point finer and sharper. Thus the German authorities, by reducing the weight of their Mauser bullet from 227 grains to 154 grains, and using an increased charge, have increased the initial velocity from 2,090 to 2,900 feet per second. The reduction in weight, the diameter remaining the same, means a decrease in the sectional density, so that the bullet has less power of overcoming the air resistance, but the effect of making the point of the bullet extremely sharp is to lessen the air resistanec to sueh an extent

that the loss of sectional density is more than made up for, and the bullet retains its velocity well at the longer as well as the shorter ranges, and has a very flat trajectory and great ranging power.[1] (See Fig. 5, E). Similarly the French, by reducing the weight of the Lebel bullet from 231 to 204 grains, have

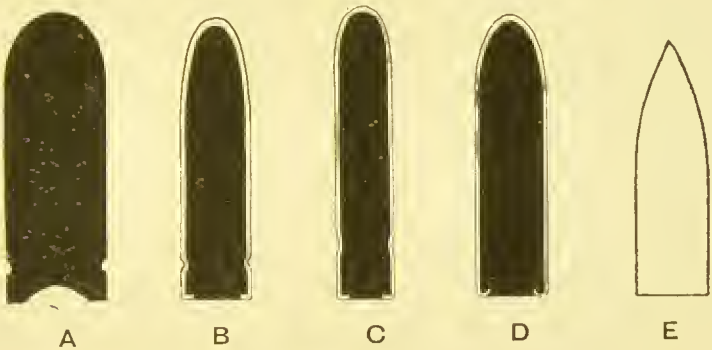


FIG. 5.

A. Section of Martini-Henry bullet (·450″).
B. Section of Lee-Enfield bullet (·311″).
C. Section of Japanese bullet (·260″).
D. Section of German Mauser bullet (·322″).
E. Outline of New German bullet, for comparison with D.

increased its initial velocity from 2,070 to 2,400 feet per second.[2] Experiments on the same lines are now in progress in this country, and will probably result in increasing the efficiency of the present rifle without alteration to the rifle itself.

[1] *Journal of the Royal Army Medical Corps*, March, 1906, p. 359.

[2] *Verhandl. Deutsch Gesellsch. f. Chir*, xxxv, 1906, p. 31.

Pistols and Revolvers.—Most military revolvers throw a leaden bullet of large calibre at a comparatively low velocity. Several of the automatie pistols throw a small-bore bullet with a hard envelope at a velocity of 1,200 to 1,400 feet per seeond. These weapons are only intended for use at short ranges, and wounds from them, except accidental wounds, are not of frequent occurrence.

Artillery Projectiles.—Common shell are hollow projectiles containing a bursting charge; they are exploded either on impact or by a time fuse, and the shell is burst into fragments of various sizes, commonly more or less irregular in shape, which are driven in all direetions by the force of the explosion of the bursting charge. They are employed chiefly for ascertaining the range, and against buildings and fortifications. The only form of common shell that is used for the purpose of killing and wounding the enemy is the Vickers-Maxim or "pom-pom" shell, weighing one pound, exploding on impact, and fired in rapid succession from an automatic weapon.

Hand grenades are merely small common shell thrown by hand at close quarters.

Shrapnel shell consist of a hollow casc containing

a large number of spherical leaden bullets and a bursting charge. They are exploded by a time fuse, and are intended to burst a short distance before reaching the enemy, so that the case is broken by the bursting charge, and the contained bullets travel onwards with the velocity they already have, spreading out so as to strike over a considerable area. The velocity of the bullets is low, and is derived from the explosion of the charge in the gun from which the shell was fired, not from the bursting charge, which is only intended to rupture the case of the shell.

Case shot consist of a thin metal case containing a large number of bullets similar to those of shrapnel, but no bursting charge. They are intended for use at short ranges; the case is ruptured by the explosion of the charge on firing, and the bullets spread out like a charge of small shot from a shot-gun.

High explosive shells, charged with lyddite, melinite, shimose, etc., are used chiefly against fortified positions. When these explode the case is broken up into very numerous small fragments, which seldom inflict severe wounds.[1] These high

[1] Follenfant, *Arch. Med. et Pharm. Mil.*, July, 1906, p. 73.

explosives may cause death from shock without any external wound. Poisonous effects have been attributed to the gases produced by the explosion of these substances, but nothing more serious than some irritation of the air passages seems to occur.[1]

[1] Follenfant, *loc. cit.*, p. 74.

CHAPTER II

GENERAL CHARACTERS OF GUNSHOT WOUNDS

THE **mechanical effects** produced by a bullet striking the body fall under three heads :

(1) In the actual track of the bullet the tissues are destroyed. The amount of destruction is lessened by the elasticity of the tissues, which allows them to give way and stretch before the bullet.

(2) The energy of the bullet is communicated to portions of the tissues, which are propelled in the general direction of the bullet's course. In this way fragments of bone may be driven through the soft parts, acting as secondary missiles, or the soft or fluid contents of a hollow organ such as the stomach or bladder, or the contents of the cranium, may be so violently impelled against the wall of the cavity in which they lie as to rupture it extensively.

(3) Vibrations are set up in the tissues, radiating in all directions from the point of impact and from the bullet's track. The effect of these is to cause

injury to delicate structures such as nervous tissues, without any gross lesion such as is produced by the bullet itself or by secondary missiles propelled by it.

The effects described under headings (2) and (3) are seen chiefly when the energy of the bullet is great, i.e., at short ranges, and when the resistance of the tissues struck is high, more especially when compact bone is struck.

The **general characters** of bullet wounds depend on the energy of the bullet, its size, its mode of impact, its stability, and the resistance of the part struck. A large amount of experimental work has been done with the object of ascertaining what kind of wounds the small-bore bullet would produce. Most of this work was done before these bullets had been used on a large scale in war. The results have proved to be misleading, the injuries produced experimentally being much more severe than those seen in actual warfare. The explanation of this fact need not detain us, it is sufficient to note that now that there is abundant evidence as to the nature of the injuries met with in war, all the evidence derived from experiments on animals or on the human cadaver may be set aside as superfluous, as well as misleading.

The **entrance wound** produced by the small-bore bullet is in its typical form circular or oval, smaller than the diameter of the bullet, owing to the elasticity of the skin, and of a punched-in appearance. The edges tend to be inverted or depressed, and the margin of the skin is covered with a slight black or grey metallic stain. If this is wiped off a narrow pink rim is seen from abrasion of the inverted edge of the skin by the bullet; this becomes brown later as it dries. More or less ecchymosis appears round the entrance wound within a short time of the receipt of the injury. Oblique impact of the bullet causes the entrance wound to be oval, and with extremely oblique impact a mere gutter may be cut on the surface. The entrance wound tends to be slightly larger at short ranges, and in regions where the skin is well supported and so cannot give way and become stretched before the bullet, as in the scalp, over the sacrum, and over the bony portions of the chest wall. In loose and unsupported skin the entrance is less regular, and may be slit-like or star-shaped, especially when the velocity of the bullet is low. These slit entrance wounds are common in the loose skin of the scrotum.

Bullets deformed before striking, as by ricochet,

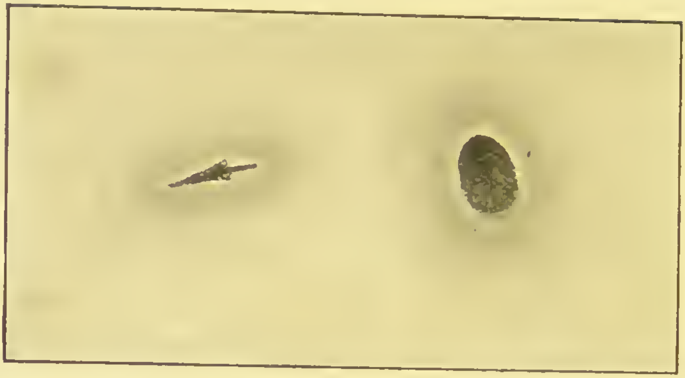


Fig. 6.—Oval Entry Wound over third sacral vertebra. Exit wound, anterior abdominal wall. Slightly starred variety. Diagram made on second day. (Makins.)

cause irregular and lacerated wounds, as do bullets that have lost their regularity of flight and so make impact base or side foremost. Bullets that break up on some hard substance just before striking may produce more than one entrance wound.

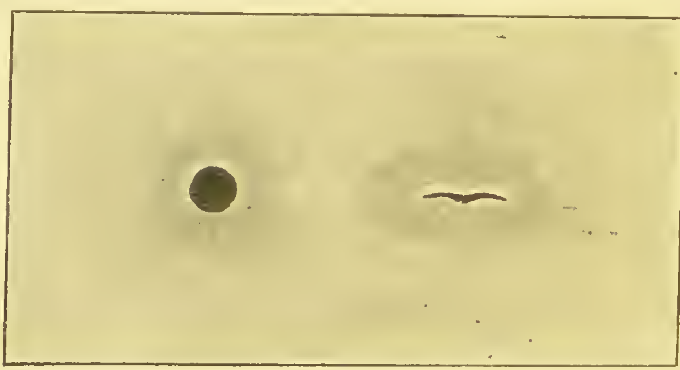


Fig. 7.—Circular Entry back of arm: exit (bird-like) in anterior elbow crease. (Makins.)

The **exit wound** is much more variable than the entrance. In very many eases it is almost exactly like the entrance wound, so mueh so that even surgeons with very wide cxperience of gunshot wounds often find it impossible to distinguish one from the other. The margins of the exit wound tend to be everted rather than depressed, and the

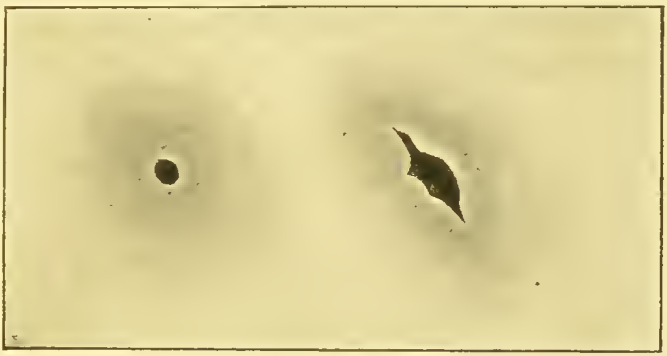


FIG. 8.—Circular Entry over patella. Starred exit of elongated form in popliteal crease. (Makins.)

subcutaneous fat may rise up into the wound or protrude from it. The skin on the exit side being unsupported, slit, starred, and valvular exits are not uneommon, especially at long ranges, the skin becoming stretched before the bullet, and giving way in its normal lincs of cleavage, whieh eorrespond to thc natural creases and folds of the skin. Oval

exit wounds are not very common, but one form must be mentioned, the "flame-shaped" exit, where the bullet passes out very obliquely, leaving an oval wound prolonged at one side by a tapering gutter which has been compared to a candle flame. If the bullet becomes deformed, as from striking compact bone, the exit wound will be large and irregular, and if the bullet breaks up it may produce more than one exit wound.

In the so-called "explosive" type of exit wound, there is a large irregular lacerated wound, the skin appearing torn and burst outwards as if an explosion had taken place inside the part. (The term "explosive" is merely descriptive, and must not be taken as implying any theory as to the causation of this class of wound.) There is a more or less funnel-shaped cavity in the soft parts, and from the large wound torn muscles and tendons protrude, mingled with splinters of bone. Lacerated nerves may be also seen in some cases. These effects are seen only at short ranges, 300 yards or less, or with the Martini-Henry bullet under 200 yards. The conditions necessary to produce them are great energy on the part of the bullet, and high resistance on the part of the tissues. They are seen only when

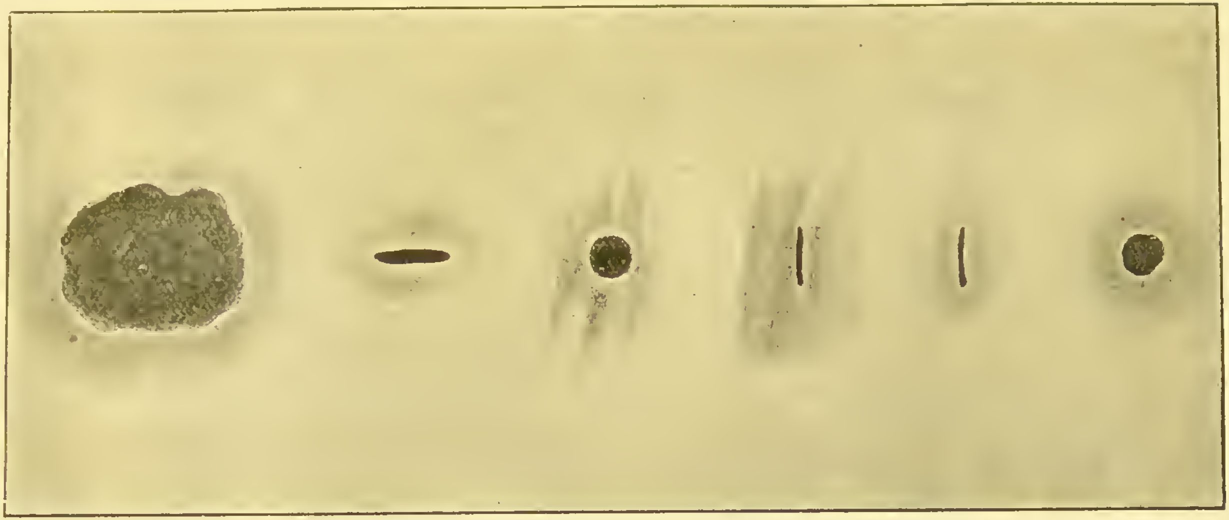


FIG. 9.—Entry and Exit Wounds in both thighs and scrotum.

From right to left: 1. Circular entry in left buttock behind trochanter. 2. Vertical slit exit in adductor region. 3. Slit entry in scrotum (probably inverted before bullet broke the surface, and then a slit occurred in a normal crease). 4. Circular exit in scrotum (here supported by surface of right thigh). 5. Transverse slit entry in right adductor region. 6. Irregular "explosive" exit, the bullet having set up on contact with the front surface of the femur, but without having caused solution of continuity of the bone. (Makins.)

the bullet has struck bone, and are produced by fragments of bone driven on by the bullet and making their exit from the part with it. Similar effects have been produced experimentally by bullets that have passed through soft parts only, without striking bone, but it is very doubtful whether this ever occurs in the living body. An exit wound of more than an inch in diameter generally indicates that the bullet has struck compact bone, though the size of the wound gives no clue to the amount of damage done to the bone. Various other explanations of the production of explosive exit wounds have been advanced, but as none of them are generally accepted they need not be discussed. They will be found in larger works on the subject. (Stevenson, *Wounds in War*, chap. ii).

The **track** of the bullet in the soft parts is a straight line from the entrance to the exit, *when the part is in exactly the position it was in at the moment it was struck.* This condition is most important, as it is often impossible to form any correct idea of the course the bullet has taken unless the position of the part at the moment it was struck is known, and usually there is only the patient's statement to depend on as to this, while if the wound has been

PLATE I.

Explosive exit wound on the inner side of the Foot.

Drawing from a photograph by Captain Prescott, R.A.M.C.

[To face page 34.

received during active movement it may be impossible to ascertain the position at the time. The old spherical bullet was easily deflected from its

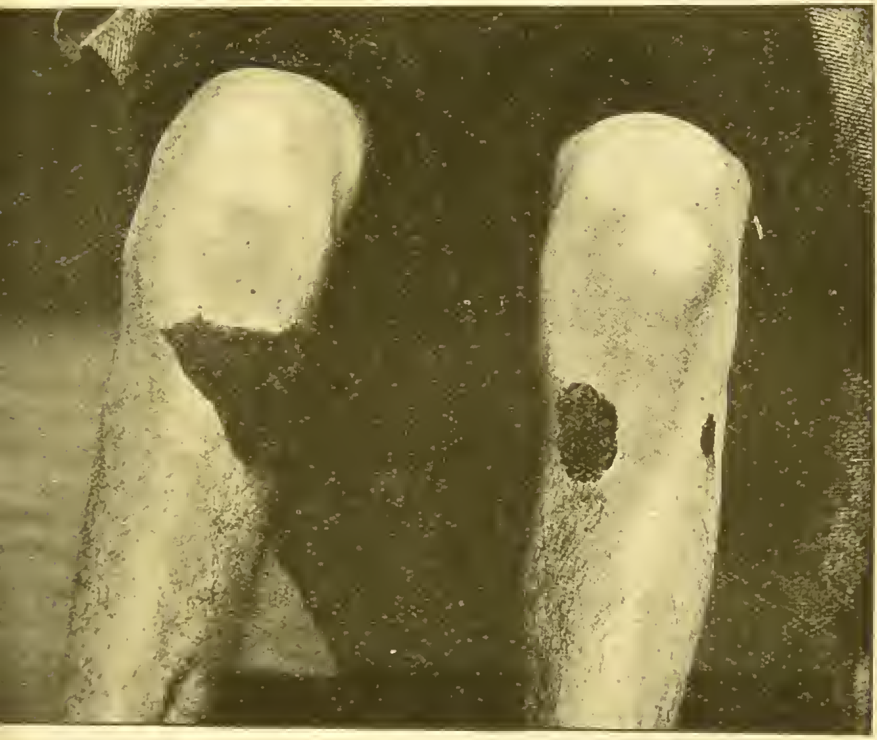


FIG. 10.—"Explosive" Wounds of Legs.

Large irregular entry ($1 \times \frac{3}{4}$ in.). First exit (2 in.) roughly circular. Second entry wound, produced by bone fragments driven out of left leg, very large and irregular ($5 \times 3\frac{1}{2}$ in.). The measurements were taken eight days after infliction of the wounds. The right limb was amputated later for secondary hæmorrhage. (Makins.)

course, and sometimes took a circuitous path round the body, following the course of a rib or the intermuscular planes. This never occurs with the small-

bore bullet, which is never defleeted from a straight course exeept by striking bone, and then seldom to any great extent. The traek in soft parts is elcanly cut, always a little larger in diameter than the entranee wound, but generally slightly smaller than the bullet. The diameter of thc traek tends to increase slightly towards the exit side, and where the bullct passes through a resistant strueture, as a dense faseia, the diametcr is often suddenly increased. Very superfieial bullet traeks arc often traccable by thc subeutaneous eeehymosis marking the course of thc bullet.

Even when the exaet posture at thc time the wound was received is known, there is often great diffieulty in forming an opinion as to the exaet path of the bullet. This is espeeially the ease when the bullet has taken a long eourse through the body. It is often impossible, in the absence of symptoms pointing elearly to injury of a particular organ or strueture, to be certain that the organ or structure in question has or has not been wounded. This applies partieularly to mobile organs, sueh as the heart and ccrtain portions of the intcstines, and to sueh struetures as vessels and ncrves. It is usually easy enough to diagnosc

perforation of large organs such as the lung or liver, but it is often impossible to say whether the intestine, the spleen, the kidney, or an artery or a nerve has been wounded or not, though it may appear to lie directly in the path of the bullet. In the absence of symptoms, the diagnosis can be cleared up in such cases only by exploration, if such a measure is justifiable.

A single bullet may cause more than one wound, as by passing through two limbs, or two portions of a flexed limb, or through a limb and the trunk.

The small-bore bullet does not often lodge in the body, except at long ranges, or when it has become deformed and has lost some of its energy through ricochet, or when it strikes compact bone. It was estimated in the Russo-Japanese war that about 10 to 20 per cent. of all missiles lodged in the body, but only 3 or 4 per cent. of rifle bullets, most of the lodged missiles being shrapnel bullets.[1] Portions of clothing are not often carried in by the small-bore bullet. The texture of the clothing is of some importance in this connection. Mr. Makins noted in South

[1] Hoff, *Journal of the Association of Military Surgeons*, August, 1906.

Africa[1] that the woollen material of the Highlanders' kilts was more often carried in than the cotton drill worn by other regiments. In Manchuria, the Russians wore coats lined with sheepskin in the winter, and the carrying in of fragments of wool from these accounted for a much greater proportion of the wounds being infected in winter, at least 30 per cent. more of the wounds being infected in winter than in summer.[2]

Small fragments of stone are not uncommonly carried into the wound when a bullet strikes stony ground close to the wounded man, even though the bullet itself may be little deformed and may pass through the part struck with very little laceration.

The larger forms of rifle bullet, such as the Martini-Henry, produce external wounds very similar in most respects to those caused by small-bore bullets, the chief difference being that they are larger, from the greater diameter of the bullet, and that irregular and lacerated wounds are more common, especially at the exit wound, from the bullet having less velocity and being softer and more easily de-

[1] Makins, *Surgical Experiences in South Africa*, p. 71.
[2] Follenfant, *Arch. Med. et Pharm. Mil.*, July, 1906, p. 77.

formed. These large bullets cause much more severe injuries to solid organs and to the cancellous ends of long bones than does the small-bore bullet.

Expanding bullets are very unlikely to be used in war by civilised nations. They produce wounds of greater severity than those caused by the normal small-bore bullet, and these wounds resemble those from soft leaden bullets in their greater irregularity and larger diameter.

The proportion of the casualties in war due to artillery projectiles has been variously estimated at from 8 or 10 per cent. to 20 or 25 per cent. of the total. The majority of these are wounds from shrapnel. The shrapnel bullet is a spherical leaden bullet travelling at a low velocity, it cuts a larger track than the rifle bullet, very often lodges in the body, causes irregular skin wounds of some size, and is very likely to carry in portions of clothing with it. Wounds from shrapnel bullets are almost invariably septic. Wounds from pieces of shell are not nearly so common as shrapnel wounds. The size of the wound depends on the size of the fragment of shell, and varies from a small puncture to most extensive laceration. The skin apertures are quite irregular, the fragments seldom penetrate deeply,

and there is much laceration and bruising of the tissues. Fragments of shell very commonly lodge, and frequently carry in pieces of the clothing. Shell wounds are always septic, and extensive early necrosis of the surrounding tissues is a marked feature. In the rare case of an unexploded shell striking the body, most extensive and severe injuries may occur, a limb may be severely mangled or completely carried away, with great laceration of the soft parts and splintering of the bones. The one-pound shell of the "pom-pom" may strike the body without exploding and produce a large wound with much laceration. These are, however, rare injuries.

A form of injury rarely seen now, but not uncommon in the days of round shot, was the so-called "wind contusion." This was a severe contusion of the deeper structures, muscles or viscera being much crushed and lacerated, and sometimes bones being broken, without any rupture of the skin. It was formerly supposed to be due to the "wind" of a shot that passed very close without actually striking, but it is quite certain that such an injury cannot be produced in that way, for many instances have been recorded of large projectiles passing at

high velocities quite close to the body without causing any injury at all, and the true explanation of "wind contusions" is that they were due to glancing contact of a projectile travelling at a low velocity, causing contusion of the underlying structures, the skin escaping through its elasticity and toughness, though it sometimes sloughed later.

The idea that bullets ever have any poisonous effect on the wound they inflict is groundless, and was exploded as long ago as the days of Ambroise Paré, though, like other superstitions, it crops up again from time to time.

It has also been supposed that the heat generated when the bullet strikes may raise its temperature sufficiently to produce a cauterising effect in the wound. There is no evidence that this ever occurs. When a bullet strikes an iron target a great deal of heat is produced, and the lead may be melted, but when the body is struck much less heat is produced, and the temperature of the bullet is not raised enough to cause any burning of the tissues. Bullets that have been recovered immediately after striking, both in experiments and in cases where bullets have lodged in a man's clothes after passing through his body, have been found hot, but not hot

enough to burn. In a very few cases such bullets have been hot enough to blister the skin against whieh they lay, but this is the nearest approach to a cauterising effeet that has been reeorded.

Certain symptoms eommon to all gunshot wounds may eonveniently be eonsidered here.

Pain varies greatly, aeeording to the sensitiveness of the individual, the part of the body struek, and the state of mental preoeeupation or exeitement at the time of reeeiving the injury. It is well known that in the heat of battle men are often wounded and remain absolutely uneonseious of having been struek at all. On the other hand, when the mental eondition is one of strain and anxiety, as when men have been exposed to fire for some time, with perhaps little ehanee of returning it, the pain of wounds is more likely to be felt aeutely. The sensation at the moment of being struek is generally a sharp stinging or burning pain, often eompared to a blow from a whip, sometimes to "being hit by a briek," or to "a blow from a sledgehammer," or to being struek with red-hot iron, In flesh wounds the pain is felt ehiefly in the skin. often more at the exit wound, and is seldom severe. Laeerated wounds, sueh as shell wounds, give rise

to more severe pain than simple punctures, and the pain is usually succeeded by numbness. When bone is struck there is intense pain at first, followed by a dull aching. In injuries to nerves the pain is often referred to the distribution of the injured nerve. The pain of a gunshot wound is seldom very severe or persistent, except in wounds of large nerves, and of the spinal cord. In multiple injuries pain may be felt only in the most sensitive part injured. Only in exceptional cases is pain very intense.

Shock also varies very much in gunshot wounds, and depends mainly on the severity of the injury. Mental conditions are of some importance as affecting the degree of shock, patients being more cheerful after a victory and making light of their wound, while after defeat they are depressed and gloomy, and this has an adverse effect on their welfare. Shock is most marked in wounds of the spine, the abdomen, the head, and in severe fractures, especially of the femur.

As instances of the absence of any marked degree of pain and shock the following cases are of interest—

(1) An officer felt "a graze in the back" from

a bullet, but continued to fight. Some hours later, to his astonishment, the bullet was found to have passed from its entrance in the left loin as far as the middle of the inner side of the thigh, whence it was removed.[1]

(2) A man shot through the buttock and abdomen was unaware that he had been hit till on undressing he found blood in his trousers, and even then his first thought was that he must have got dysentery! The injury caused death in thirty-six hours.[2]

(3) In another case a Martini bullet passed through the arm and chest, finally striking the chin and fracturing the lower jaw. The patient felt pain only in the chin, and the other wounds were discovered when he was undressed.[3]

A very interesting and important condition, and one peculiar to gunshot wounds, is that known as **local shock.** This consists in localised anæsthesia and numbness in the neighbourhood of the wound, with temporary paralysis of the muscles of the part. It must be distinguished from lesion of a main nerve trunk, leading to paraly-

[1] *Report on Surgical Cases, South Africa*, p. 148.
[2] Makins, *loc. cit.*, p. 104.
[3] Makins, *loc. cit.*, p. 103.

sis and anæsthesia in the distribution of the nerve. The symptoms are localised to the vicinity of the wound, and do not correspond to the distribution of any particular nerve. This condition is due to the vibrations set up by the impact of the bullet acting on the finer nerve filaments and nerve-endings, and causing temporary loss of function in them. Local shock is most marked at short ranges, when the energy of the bullet is great, and is generally more pronounced near the entrance wound. It appears very soon after the receipt of the wound, and lasts from a few hours to a day or two. In cases in which local shock is well marked the vitality of the tissues appears to be lowered to some extent, and such wounds are more readily infected. Local shock is well marked in gunshot fractures, and the loss of muscular tone diminishes the tendency to displacement at first, but as this passes off and the muscles recover displacement becomes more marked, an important point in treatment.

Severe primary **hæmorrhage** from gunshot wounds is not often seen in cases that are brought into hospital. Cases in which there is free bleeding from a large vessel mostly die on the field before

assistance can reach them. The small-bore bullet cuts clean notches or perforations in large vessels, but owing to the narrowness of the track and the ease with which it becomes occluded by a slight change in the position of the part or by clot, the blood does not readily escape externally, and hæmorrhage occurs either into the tissues or into one of the serous cavities. In the trunk, wounds of large vessels are often rapidly fatal from internal hæmorrhage. In the limbs, bleeding from a wounded vessel tends to become spontaneously arrested in most cases, or takes place into the tissues, forming a traumatic aneurysm. Men that die on the field are sometimes found lying in pools of blood, but not often.

Infection in Gunshot Wounds.—The clinical course of a gunshot wound depends chiefly on whether it remains aseptic or becomes infected. Aseptic wounds heal rapidly, the skin apertures close in a few days, and the deeper parts of the track take a little longer to heal than the skin wounds. Whether a gunshot wound remains aseptic or not depends to a large extent on the size of the skin apertures and on the amount of damage done to the tissues. Where there are the normal small

entranee and exit wounds, and no great laeeration of the deeper parts, as in a simple flesh wound of a limb, there is little or no hæmorrhage or oozing of serum, the external apertures beeome sealed at onee by small dry seabs, or by the applieation of a first field dressing, and there is very little likelihood of infeetion taking plaee. If, on the other hand, there is mueh laeeration, with large skin wounds, as in " explosive " wounds or the lacerated wounds produeed by shell fragments, and espeeially in severely eomminuted fraetures with large skin wounds, the amount of serous diseharge is eonsiderable, and there is very great diffieulty in preventing sueh wounds beeoming infeeted. The great majority of small-bore bullet wounds may be eonsidered aseptie in the first instanee, exeept in the eomparatively small proportion where the bullet has earried in portions of elothing with it, or has opened up a septie region, as the intestine. This faet is interesting when one eonsiders that the bullet has usually been earried in a dirty poueh or bandolier, and handled by dirty hands, and moreover that the skin through whieh it enters is praetieally always very far from elean and must be rieh in pyogenie organisms.

Thc sides of the bullet are seraped clean and most of the surfaee renewed as it passcs along the barrel of the rifle, and its base is effcctually sterilised by the heat of the burning explosive, so that only the point remains soiled. Experiments, however, havc shown that if bullets are infected with easily recognised organisms and then fired into various substances, the organisms ean be recovered and grown from thcm, so that the point of the bullet does not becomc sterilised by firing. The explanation of the wound so often remaining aseptie probably is that the organisms on the bullet and on the area of skin struck by it are widely scattered along the traek, and very few of them lodge at any one spot, so that they are too few in number at any point to ovcrcome the resistance of the tissues to their development. It is wcll known that the tissucs are eapable of dealing with and overeoming organisms that are present in small numbers, and that most "aseptie" operation wounds really eontain some organisms, although the wounds heal without suppuration. Infeetion of gunshot wounds commonly takes place from the elothing or the surrounding skin, and unfortunatcly in too many cases from interfercnee by thc surgeon or others,

especially through faulty technique in changing dressings, and occasionally through ill-advised attempts to remove lodged missiles that would better be left alone. Plugging wounds for hæmorrhage is a sure way of infecting them. Infection may also take place from within, especially when the bullet has traversed some part of the alimentary canal, and a bullet may carry infective material from the stomach or intestine to a distant part of its track, as to the interior of the liver, or the pleura. When suppuration occurs, it is usually of mild type and shows little tendency to spread beyond the bullet track, provided good drainage is secured, though owing to the depth of the track healing is often very slow and tedious. General infective wound diseases are rare, tetanus was very seldom seen in South Africa, and in Manchuria it occurred in about 2 per 1,000 of the wounded in the Russian troops, there being some 250 cases in all, with a mortality of 87 per cent. Erysipelas occurred in about five cases per 1,000 of the wounded in the Russian army.[1]

The "septicæmia" so often met with in reports of recent campaigns is not true septicæmia, but

[1] Hoff, *loc. cit.*

septic poisoning from prolonged suppuration and absorption of toxins, and would more properly be called sapræmia or toxæmia, though the term septicæmia is generally but inaccurately used. Pyæmia, formerly the scourge of military surgery, is extremely rare under modern conditions, and the same may be said of hospital gangrene. The disappearance of these diseases, in spite of the fact that large numbers of suppurating wounds have to be treated, often in confined spaces, is due partly to improved sanitation in general, and still more to a rational system of wound treatment.

Causes of Death.—Death on the field is due in a comparatively small number of cases to direct injury of a vital part, as the brain or upper cervical region of the spinal cord. In a few instances death may occur from shock, in very severe or extensive injuries. Apart from these cases, by far the greater number of deaths on the battle-field is due to hæmorrhage, chiefly internal hæmorrhage from wounds of the heart and the great vessels of the thorax and abdomen. Fatal hæmorrhage does not so readily take place from vessels of the limbs, unless the wound in the vessel communicates

directly with the surface, so that free external hæmorrhage can occur; in most cases the bullet track is so readily blocked by clot, or by some slight change in the position of the part, that the blood cannot escape externally, and accumulates in the tissues, gradually causing hæmorrhage to cease as the pressure of the extravasated blood increases. Where a large artery is wounded and there is free exit for the blood, death is very likely to follow before aid reaches the patient, and this is not uncommon in wounds about the root of the neck as well as in the limbs.

Of the cases that survive to reach a hospital, a few die in the first forty-eight hours from shock and hæmorrhage, but apart from these, all the deaths among the wounded are due directly or indirectly to **infection of the wound**, either from without or from injury of the alimentary canal. The only exceptions are the very rare cases in which hæmorrhage occurs from rupture of the wall of a contused artery in an aseptic wound, or from the rupture of a traumatic aneurysm; also the few cases that die from the shock of amputation, which is, however, generally undertaken on account of septic complications.

Treatment.—The general symptoms, shock, pain, and loss of blood must be treated as in any other case of injury. Morphine is of special value to the military surgeon, as it enables the sufferings of the patient to be alleviated while he is being carried from the field to the hospital, and the administration of morphine and of hot beef-tea or soup is one of the first things to be done for all cases of serious injury, in the absence of any contra-indications.

In the treatment of the wound itself the important points are to arrest any dangerous hæmorrhage that may be going on, and to prevent infection of the wound. Of these the latter is by far the more important; hæmorrhage very seldom calls for active treatment, but on the prevention of infection the fate of the patient depends; it is a matter of life or death in many cases, and determines in all whether convalescence shall be lingering and painful, or rapid and free from complications.

The treatment may be considered under three conditions: (1) First Aid on the field, (2) treatment in the field ambulance, and (3) treatment in a fixed hospital.

First Aid can seldom be given at once by a medical

officer or a trained orderly. In modern battles it is usually impossible to push the first line of medical assistance as far forward as the firing line, and any attempt to do so would involve heavy casualties among the medical *personnel*, who cannot easily be replaced, and would cause needless risk to the wounded. The number of wounded in a general engagement is so great that it is impossible to attend to them all immediately, and it may be some hours before aid can be brought to all. First aid will often be rendered by a comrade, or in some cases by the patient himself, and all ranks are taught how to apply the first field dressing. The application of a tourniquet is very seldom necessary.

The **first field dressing** at present issued consists of a small package in a waterproof cover, containing two pieces of sal alembroth gauze, a piece of wool between two layers of gauze, a folded gauze bandage, and two safety pins. The wool and gauze are intended to be placed on the wounds, and secured by the bandage. The object of the first field dressing is to prevent soiling of the wound, and at the same time to allow of evaporation, so that the wound quickly becomes sealed by the drying of the blood and serum in the dressing. No

impervious material should be used to cover the dressing, as was at one time recommended. Double cyanide gauze would be less irritating than the sal alembroth gauze now used. The Japanese first field dressing contains three pieces of gauze and a triangular bandage. The German pattern has the pad of gauze sewn to the bandage in such a way that it can be applied to the wound without being touched by the fingers.[1] The method of applying the first field dressing is important. The wound must on no account be wiped, any wiping merely carries dirt into the wound from the surrounding skin. The gauze must be handled as little as possible, and must be placed straight on the wound and secured by means of the bandage. It is necessary to impress these points on the men themselves, so that they may avoid doing more harm than good in attempting to apply the dressing, and they should be warned not to touch the wound, not to let the dressing material fall on the ground, and not to touch with the fingers the part of the gauze actually to be placed in contact with the wound.

Various modifications of the first field dressing

[1] *Archives de Médecine et de Pharmacie Militaires*, July, 1907.

have been suggested. The use of some antiseptic powder or paste has been recommended. The objection to powders is that they make the dressing more apt to slip, besides being unnecessary. Pastes are also objectionable, as they cannot well be applied by unskilled men, and would have to be carried in collapsible tubes, which would not stand the rough usage a first field dressing has to undergo. These dressings are carried by the soldier in his pocket, perhaps for weeks or months, and they must not contain any substance likely to be damaged and to render the whole contents of the package unserviceable when it is wanted for use.

In Manchuria the Russians tried painting the skin round the edges of the wound with an alcoholic solution of iodine, with the object of disinfecting the skin and so preventing infection of the wound. Experience soon showed that this, so far from preventing infection, actually favoured it, as the skin became irritated and dermatitis was set up by the iodine. Von Oettingen applied a tablet of collargol to the wound, and then put on a gauze dressing, having first painted a sticky mixture of alcohol and turpentine round the wound to make the dressing adhere. This dressing gave good results in his

hands, but is altogether unsuited for use by any one but a surgeon, and the necessary materials could not be carried in the first dressing packet. Balsam of Peru has been suggested to fix the dressing and act as a mild antiseptic, but is open to the same objections. The first dressing must be as simple as possible, and all complications are better avoided.

In cases of fracture, improvised splints must be applied as soon as the wounds have been dressed. The various ways in which splints can be improvised are so well known that there is no need to detail them here. Quick work is of the greatest importance in the field, and no time should be wasted in applying elaborate apparatus. In many cases all that is really necessary is to tie the lower limbs together, or to fix the upper limb to the chest.

A very simple and practical method of roughly classifying the wounded was adopted by the Russian surgeons in Manchuria. Every surgeon carried a red and blue pencil, and after applying the first dressing the bandage was marked with a red cross if the injury was a severe one needing immediate attention at the dressing station or field ambulance, with a blue cross if the case was not urgent and merely required dressing, and if the injury was a

slight one and the patient could be passed on to the hospitals in rear without any further treatment no mark was put on the dressing.

The second stage of treatment is that given in the field ambulance or other mobile hospital that accompanies the troops, collects the wounded after an engagement, and passes them on to the hospitals in rear of the army. It is here that the limitations of surgery in the field are most in evidence, and the conditions under which treatment has to be carried out necessarily modify the treatment very greatly.

In the first place, there is very great pressure of work, often overwhelming in amount. After an engagement of any importance the wounded are brought in by hundreds or by thousands, and this enormous number of wounds must be dealt with as rapidly as possible by a limited number of surgeons.

Then there are very great difficulties in attaining asepsis. Water is sometimes very scarce, and what water there is may be dirty, as was often the case in South Africa. Fuel to boil water and sterilise instruments may not be obtainable. Work must be done in a tent, or in the open air exposed to dust,

flies, and all kinds of climatic conditions, such as high winds, rain, excessive heat or extreme cold.

The amount of material that can be carried in a movable hospital is necessarily very limited. No bulky or elaborate apparatus for sterilising can be carried, and owing to the difficulty of replenishing supplies of dressing material, rigid economy must be observed.

There are great difficulties in nursing and feeding the cases. Female nurses cannot be employed in these hospitals, and only a limited number of male nurses is available. The food available is the ordinary field ration, supplemented by such articles as tinned milk, meat extracts, and stimulants.

Perhaps the greatest difficulty in the treatment of the wounded in the movable hospitals is the necessity of moving the cases within a very short time of their arrival. The field ambulance must move with the troops to whom it is attached, and that means that it must be cleared of wounded within a few hours or days after the last engagement, so as to move off with the troops. All the wounded must be evacuated towards the hospitals in rear of the army as soon as possible, and this makes it impossible to carry out the ordinary after-treatment

of surgical cases, and limits operative treatment to a very great extent.

Some of these difficulties may not be met with in fighting in civilised countries, and some may be overcome by improved organisation, but the enormous pressure of work and the enforced transport of the cases will always have to be faced.

Treatment in the movable field ambulance must, therefore, be limited to the application of suitable dressings with a view to the transport of the cases to the hospitals in the rear. Many of the slighter injuries need not be touched, the first field dressing may be left unchanged. When the dressings are changed, the skin must be carefully and thoroughly cleansed, and shaved if necessary, the wound being carefully protected during this process. The new dressing should be of sufficient size to last for some days without renewal, and must be carefully fixed, so as not to shift during the journey to the base. Fractures must be immobilised as carefully as possible. No probing or exploration of the wound should be attempted. No operation should be undertaken that can possibly be avoided. The only cases that must be operated on are those few in which dangerous hæmorrhage is going on, and

cases in which tracheotomy must be done for urgent obstruction of the upper air passages, in some wounds of the larynx. Both these classes of case are rare. Amputations should never be done in the field ambulance, as the transport causes them to do very badly.

If the dressings become soiled or shift during the journey to the rear, it is better to change the outer layers only, and avoid uncovering the wound if possible.

When the patient arrives at a fixed hospital, where none of the difficulties that hamper surgical work in the field are met with, and where it is possible to have a properly equipped and staffed operating room, good nursing, and all the conveniences of a well equipped hospital, any operative procedure necessary can be carried out under satisfactory conditions and with a fair prospect of success. X-rays will be available for diagnosis in cases of fracture and of lodgment of bullets or other missiles.

The question of removal of lodged bullets may be briefly dealt with here. For their detection and localisation X-rays will give all the information necessary, and all the ingenious electrical apparatus designed for finding lodged bullets has been super-

seded by X-rays. Lodged bullets are often removed unnecessarily. They should be left alone unless there is some definite reason for removing them. In many situations a lodged bullet will remain for years without giving rise to any trouble, and harm may be done by ill-advised attempts at removal. A bullet should never be removed merely because it is easily accessible, and under no circumstances should a lodged bullet be interfered with in the field ambulance; many wounds have been infected through disregard of this salutary rule. If a bullet is causing trouble, keeping up discharge from a sinus, causing pain from pressure on a nerve, or interfering with the movement of the part, it should be removed, and bullets that lie in regions where they are likely to cause trouble, as in the neighbourhood of a joint, in the pleural cavity, or in the cranium, if accessible, should be removed. If the removal of a bullet is decided on, it should be localised as accurately as possible, and an incision planned to reach it by whatever route gives the best access. Sometimes enlarging the entrance wound suffices. No attempt should ever be made to drag a bullet out by the track it went in by, and bullet forceps should never be used for this purpose except in the case

of a large missile or a fragment of shell lying superficially. The old method of groping in the dark for bullets with various ingenious and dangerous forceps is not only objectionable, it is impossible in the narrow track made by the modern bullet.

CHAPTER III

WOUNDS OF BLOOD VESSELS

It is a remarkable fact that arteries not unfrequently escape injury when they appear to lie directly in the track of a bullet. The absence of any signs of injury to the vessel in such cases has given rise to a good deal of discussion. Possibly in some instances a wound of the vessel has really occurred, without giving rise to hæmorrhage or any other sign. This is not the probable explanation of most of these cases, and when one considers on the one hand how fine and limited the track of the modern bullet is, and on the other hand how elastic and mobile arteries are, it is quite conceivable that an artery may slip aside before a bullet, and so either escape injury altogether or receive only so slight a degree of contusion that no symptoms of any kind result. This is more likely to occur when the velocity of the bullet is low, and when the tissues of the part are relaxed so as to increase the mobility of the artery. It must also be remembered that our ana-

tomical knowledge of the variations in the course of vessels in different individuals should convince us that it is impossible to lay down with certainty the exaet position of even one of the larger blood vessels in a limb, in any given part of its course, within a fraction of an inch, nor can we judge the course of a bullet within the same small limits of error, and as the bullet traek is less than one-third of an inch in diameter, the error of observation may aceount for the escape of the artery from injury.

The injuries of arteries met with are *contusion*, *partial division*, and *complete division*.

Contusion of an artery includes all degrees of injuries to the wall of the vessel that do not open up the lumen. These vary from the slightest graze of the outer coat to an injury sufficiently severe to cause subsequent necrosis of the whole thickness of the wall of the vessel. The inner and middle coats may be ruptured in some eases without laeeration of the outer eoat. Sueh injuries are produced by lateral contaet of the bullet with the vessel, and are more likely to be caused by the larger forms of projectile, or by the small-bore bullet at low velocities.

The results of contusions of arteries are—

(1) Recovery without any symptoms. This is a purely hypothetical result, as in such a case the diagnosis of contusion could not be made. No doubt slightly contused arteries do recover and give no sign, but in that case the artery could not be distinguished clinically from an uninjured one.

(2) Thrombosis of the vessel, leading to its obliteration.[1] This is more likely to happen if the inner and middle coats are ruptured. It is a rare result of mere contusion of an artery.

(3) In severe contusions, the damaged portion of the vessel wall may necrose and give way, especially if the wound is septic. This usually happens about ten days to a fortnight after the receipt of the wound, sometimes later. Secondary hæmorrhage, or a traumatic aneurysm secondary as regards its time of onset, results. In the very rare event of the giving way of the wall of a contused artery in an aseptic wound, secondary hæmorrhage from an aseptic wound may occur.

As a late result of a bullet passing close to an artery, the vessel may be pressed upon or dragged

[1] See case, Makins, *Surgical Experiences in South Africa*, p. 112.

on by the contraction of the scar. This may seriously impede the flow of blood through it, and the pulse below may be much diminished. A murmur may be heard in some of these cases at the point where the vessel is compressed. These effects are not of any great practical importance, as they are brought about very gradually, and the collateral circulation has plenty of time to become established. The possibility of primary injury to the artery cannot be excluded in cases in which these late signs of obstruction to the circulation in the vessel appear ; contusion or even perforation of the artery may have taken place. It is well known that even large arteries may be wounded without any serious hæmorrhage occurring.

Perforating Wounds of Arteries.—The form and extent of the injury to the vessel depend on the relative sizes of the artery and the bullet, on the nature of the missile, and on the manner in which the vessel is struck. The small-bore bullet cuts a portion of the wall of the vessel clean away, producing a notch if it strikes the side of the vessel, the notch being larger the more oblique the track of the bullet is to the line of the artery. If the bullet strikes the artery in the

centre, it will completely divide a small artery, and will pierce a larger artery by two circular holes in opposite walls. From the clean-cut nature of the wounds, and the fact that the vessel is more commonly not completely divided, retraction cannot take place and the natural arrest of hæmorrhage is therefore impeded. The larger bullets and fragments of shells lacerate vessels, and more often divide them completely, so that hæmorrhage is less likely to occur.

Sharp splinters of bone, or fragments of the bullet or of its envelope, may lacerate vessels.

When an artery is completely divided there is loss of pulsation in the distal part of it, until the collateral circulation has become well established, except in regions where the anastomoses are very free. If the artery is partially divided the pulse in its distal part may generally still be felt, though it may be much diminished as compared with that on the opposite side.

All the forms of injury just described are met with also in **veins**, but in the veins of the neck and limbs they are of little importance, as hæmorrhage can generally be controlled without difficulty by elevating the part and applying slight

pressure. Wounds of the great veins of the trunk, the vena cava, innominate, or iliac veins, or the larger branches of the portal vein, must usually be fatal. Wounds of peripheral veins are chiefly of importance as influencing the occurrence of arterio-venous aneurysms, and from the greater danger of gangrene occurring if both the main artery and the main vein of a limb are wounded. Septic thrombosis of a vein leading to embolic pyæmia is very rare, and entry of air into a vein can hardly occur along the narrow track of a bullet wound.

The results of wounds of vessels are—Thrombosis and obliteration. Hæmorrhage—primary, recurrent, and secondary. Traumatic aneurysm. Arterio-venous communications.

Of thrombosis and obliteration of the vessel no more need be said. It is the common result of any perforating wound of an artery, and occurs in the natural process of healing, except when the injury results in the formation of a traumatic aneurysm or a communication with a vein.

Major Holt describes an interesting case showing the condition of a large artery some time after spontaneous arrest of hæmorrhage. He writes—"In dissecting out the upper end of the divided

ulnar nerve in the upper arm I came across the *divided* brachial artery tied up in the scar tissue. Astonishment and curiosity led me to free the proximal end, and it at once bled as a normal brachial would. I tied it, and to confirm matters eventually found the lower end also in the scar. Next day I asked the patient how it was he survived; he only said he 'bled a bit,' and then he supposed he fainted. Nothing but actual experience of the condition would have led me to believe it."

Primary Hæmorrhage.—Severe external hæmorrhage is decidedly rarely seen from gunshot wounds. Although the arterial lesions produced by the modern bullet are such that the natural arrest of hæmorrhage by retraction of the artery and thrombosis cannot easily occur, still, owing to the narrowness of the track, it readily becomes blocked either from some change in the position of the part causing the portions of the track through different layers of muscle no longer to coincide, or from the blood clotting in the track. Thus the blood as a rule cannot escape freely by the wound, and collects in the tissues, forming a traumatic aneurysm. The experience of surgeons in both South Africa and Manchuria was that tourniquets

were hardly ever required, and operations for primary hæmorrhage were very rarely performed. When external hæmorrhage does occur, it is more likely to come from the exit wound, as this is often larger than the wound of entry. If the exit wound is on the side of the limb on which the main vessels run, damage to the vessels by fragments of bone in fracture cases is more likely to occur. External hæmorrhage is more likely to be free when the artery is superficial and the bullet track leads directly from the wounded artery to the surface; and where a large artery is wounded and free bleeding occurs the patient generally dies before aid reaches him. The infrequency of severe bleeding from gunshot wounds is therefore more apparent than real, only those cases in which the bleeding has become arrested surviving to come under observation. In some very rare instances hæmorrhage may be temporarily checked by impaction of the missile in the wall of the vessel; this has been known to occur even in the aorta.[1] It is much less likely to happen with the small-bore bullet than with the bullets formerly in use.

Internal hæmorrhage is generally rapidly fatal

[1] Longmore, *Gunshot Injuries*, 2nd ed., p. 217.

if the wounded vessel is of any size, and even from small vessels hæmorrhage may continue with a fatal result. There is little or no tendency to arrest of bleeding into one of the cavities of the body, as the blood does not accumulate under pressure, and there is no tendency to early coagulation. Hæmorrhage into the thorax and the abdomen will be dealt with under wounds of those regions.

Intermediate or Recurrent Hæmorrhage takes place as shock passes off and the blood-pressure rises, and in many cases is set up by the disturbance of the patient in transporting him from the field, or from the field ambulance towards the base. It occurs both from the vessels of the limbs and from those of the thorax and abdomen. It is really delayed primary hæmorrhage, and must be treated on exactly the same lines.

Treatment of primary and recurrent hæmorrhage. If the bleeding has ceased when the patient is seen, or if it is only slight and is readily controlled by pressure, no immediate interference is necessary. The patient should be kept perfectly quiet on his back, and carefully watched in case bleeding should recommence. Stimulation should be avoided. A tourniquet may be placed loosely in position, ready

to be tightened if there is any return of the bleeding.

If bleeding persists or recurs, operation is necessary.

Plugging gunshot wounds to stop hæmorrhage is unsound, and if done on the field is a fertile source of infection. When a tourniquet has been applied it must be left on for only the shortest time possible, or gangrene of the limb will occur. The operation of choice for hæmorrhage is ligature of the wounded vessel at the injured spot, tying both ends of a divided vessel, and placing ligatures above and below the wound in one partially divided. Proximal ligature of the main artery is not to be recommended, on account of the possibility of the wrong artery being tied, and also because proximal ligature for hæmorrhage may on the one hand fail to arrest the bleeding, and may on the other hand arrest the circulation to such an extent as to cause gangrene of the limb, or in the case of ligature of the common carotid, cerebral thrombosis. If the vein is wounded as well as the artery the danger of gangrene is greater. Although proximal ligature has been done successfully in many cases, and may sometimes be the only possible operation, it should not be done unless direct ligature at the injured

spot is for any reason impracticable. Suture of the wound in the arterial wall is unlikely to be feasible, owing to the nature of the lesion being unsuitable for suture, and to the impossibility of performing so delicate an operation under the adverse conditions of field surgery.

Should the attempt to tie the injured vessel in the wound fail, the choice then lies between proximal ligature and amputation (in a limb). It is better to try proximal ligature first, reserving amputation as the last resource. If the bleeding persists after proximal ligature, or if gangrene sets in, amputation must be done at the level at which the artery was tied. Amputation for primary hæmorrhage is scarcely ever necessary.

Secondary Hæmorrhage, though rarely seen in peace conditions, is not uncommon in gunshot wounds. It may in rare cases be due to the giving way of the wall of a contused artery, or to a sharp fragment of bone ulcerating into an artery, but the common cause of secondary hæmorrhage is infection of the wound and breaking down of the clot in the wounded vessel. The exigencies of transport increase the danger of secondary hæmorrhage, both by the disturbance to which the wounded

parts are subjected and by the increased risk of infection of the wound occurring during the journey. Giving way of the sac of a traumatic aneurysm during transport is another cause of secondary hæmorrhage.

Secondary hæmorrhage is commoner in wounds from shrapnel and fragments of shell, because these wounds are more often septic. The bleeding may be from the distal end of the injured vessel. It occurs as repeated losses of blood, which may at first be small, but are followed sooner or later by more copious bleeding. Spontaneous arrest of the bleeding is very unlikely to occur, as the causes that gave rise to it are still present. In the treatment of secondary hæmorrhage, tourniquets, plugging, and pressure are useless, except as temporary expedients while preparations are being made for operation. Even if the bleeding ceases it is sure to recur, and a serious or fatal loss of blood may take place at any moment. The wound must be opened up in every case, and an attempt made to tie both ends of the bleeding vessel. The objections to proximal ligature as the operation of choice are the same as in the case of primary hæmorrhage, although it must be admitted that proximal ligature

has been successful in a number of cases, and that cases may occur in which the surgeon may feel justified in tying the artery above instead of seeking it in the wound.

Direct ligature of the bleeding vessel in secondary hæmorrhage is often a very difficult operation, the artery has to be sought for in a septic wound, the anatomy is obscured and the tissues stained, the bleeding may have temporarily ceased and so afford no guide to the wounded vessel, and the artery when found may be softened by inflammation and be too soft to hold a ligature. Sometimes, if a ligature cannot be applied, pressure forceps may be left on. If it is impossible to secure the artery in the wound, either proximal ligature or amputation must be decided on. The difficulty of decision is great, the patient may be so weak from loss of blood and a prolonged search for the vessel that amputation would probably prove immediately fatal, and on the other hand the circulation in the limb may be so impaired that gangrene is very likely to result if the artery is tied higher up, or if the collateral circulation is sufficient to prevent any risk of gangrene, it may be sufficient to keep up the hæmorrhage. Each case must be decided on its merits, having regard

to the condition of the patient and of the limb. In most cases proximal ligature may be tried, and if this fails to stop the bleeding, or gangrene occurs, amputation must then be performed. The danger of gangrene after proximal ligature is greater in the lower limb than in the upper.

Traumatic Aneurysms are very common results of wounds from the small-bore bullet. They occur in two forms, diffuse and circumscribed, which differ in the size and extent of the extravasation.

A "Diffuse Traumatic Aneurysm" is not an aneurysm at all, but a form of primary hæmorrhage, the bleeding taking place into the tissues instead of externally. It would be better called an arterial hæmatoma. The wounded artery continues to bleed, but the blood is not able to escape by the bullet track, owing to this having become blocked by clot, or by some change in the position of the part, and so extravasation takes place into the tissues, which are often widely dissected up by the blood, the pressure of which may cause considerable tension in the part and may seriously obstruct the venous circulation. As the result of the giving way of a contused artery a traumatic aneurysm may form at a late date, ten days to a

month after the receipt of the wound. An interesting case[1] is reported by Surgeon-General Stevenson, in which the third part of the axillary artery was grazed by a Mauser bullet, and on the twelfth day the artery gave way, a diffuse aneurysm forming in the axilla, which was laid open and the artery tied, successfully.

Accompanying these hæmatomata there is some rise of temperature, which may cause the condition to be mistaken for an abscess or cellulitis. The explanation commonly given of this rise of temperature is that it is due to the absorption of "fibrin ferment" from the extravasated blood, but recent researches point to the presence of the staphylococcus albus as the probable cause of pyrexia, not only in hæmatomata but also in hæmarthrosis and hæmothorax, though further proof is needed before this explanation can be unreservedly accepted. Evacuation of the blood at once reduces the temperature to normal. In some cases the blood tends to travel along the bullet track; in a case[2] that occurred in South Africa the sciatic artery was wounded and

[1] *Wounds in War*, p. 108; and *Report on Surgical Cases, South Africa*, p. 230, case 28.

[2] *Report on Surgical Cases, South Africa*, p. 242, case 115.

the blood followed the track of the bullet to the front of the thigh, forming a pulsating swelling in Searpa's triangle.

The treatment of diffuse traumatie aneurysms is on the same lines as that of external primary hæmorrhage. If the bleeding has ceased, as evideneed by the swelling having ceased to enlarge, and if the tension in the part is not great, nothing need be done beyond keeping the patient and the part at rest. If bleeding is still going on, or the tension in the part is great and the eireulation in the limb obstrueted, the eavity should be laid open, the clot turned out, and the artery tied at the wounded point. This ean usually be done without great difficulty. Proximal ligature has the same drawbaeks as in the case of external primary hæmorrhage, with the additional disadvantage that owing to the pressure of the extravasated blood obstructing the eollateral eireulation and the venous return, there is greater danger of gangrene oceurring. If proximal ligature is done the clots should be turned out by a separate ineision, to relieve tension. A number of eases were sueeessfully treated in South Africa by proximal ligature. Of forty-five cases reported in detail, direct ligature

was done in twenty-seven, with no death and one amputation for recurrent hæmorrhage. In ten of these cases the vein had also to be tied. Proximal ligature was done in sixteen cases, with removal of the clot by a separate incision in two of the cases. None of these cases died, and in only one gangrene occurred, after ligature of the femoral artery.[1]

In a **Circumscribed Traumatic Aneurysm** the spread of the extravasated blood is limited by the resistance of the tissues, which become condensed and form a false sac. This is more likely to occur when the artery is of small size, the wound in it small, and the tissues of the part firm and dense. There is a definite firm-walled tumour, usually with expansile pulsation and a murmur. Under the influence of complete rest these aneurysms have at first a considerable tendency to contract and become firmer, and in some cases they may disappear altogether, though this is an exceptional result. As a rule they tend later to become larger, and eventually to rupture either externally or into the tissues, becoming converted into the diffuse form in the latter event. They must be treated on the same lines as true aneurysms. The

[1] *Report*, pp. 221, 222.

Hunterian operation of ligature of the artery on the proximal side is usually successful, though it may be followed by the same accidents as when performed for non-traumatic aneurysms. Surgeon-General Stevenson refers to two cases[1] in which gangrene occurred after ligature for circumscribed traumatic aneurysm. The best treatment, if it be practicable, is to tie the artery close above and below the sac and excise the sac. If this is not possible, the artery may be tied close above the sac, and in cases where it is not advisable to attempt this the Hunterian operation remains.

Mr. Makins records an instructive case,[2] in which the bullet entered the second left intercostal space and was retained in the thorax. Hæmoptysis gave evidence that the lung was wounded, there was left hæmothorax, and the left radial pulse was almost imperceptible. The entrance wound suppurated, and three weeks after the receipt of the injury an incision was made into the chest and breaking down blood clot was evacuated. A fortnight later severe hæmorrhage suddenly occurred from the entrance wound, and the patient died.

[1] *Wounds in War*, p. 445.

[2] Makins, *Surgical Experiences in South Africa*, p. 127.

At the post mortem a traumatic aneurysm the size of an orange was found in connection with a wound in the first part of the left subclavian that admitted the tip of the forefinger. The noteworthy points about this case are the absence of severe primary hæmorrhage from a wound of so large an artery, and the fact that the only sign of the artery having been wounded was the diminution of the pulse in its distal part.

Arterio-venous Communications.—These, though rarely seen in civil practice, are quite common results of wounds from the small-bore bullet. They are due to simultaneous injury of an artery and its companion vein, the artery not being completely divided. Complete division of an artery gives rise to a traumatic aneurysm, generally diffuse, not to an arterio-venous aneurysm, even when the vein also is wounded. The bullet may pass across the line of the artery and vein, notching both on corresponding aspects, or it may pass between the artery and the vein, so that they are notched on contiguous surfaces; or either or both may be cleanly perforated.

There are two forms of arterio-venous communication, the **aneurysmal varix**, in which the

artery and vein communicate directly and there is no aneurysmal sac; and the **varicose aneurysm,** in which there is a sac as well as a communication between the artery and the vein. The commoner form is the aneurysmal varix. Whether a sac is formed or not depends on the nature of the injury and the relations of the vessels. A sac is less likely to be formed when the artery and vein are closely apposed, firmly bound together, and when the communication between them is direct and free, so that blood escaping from the artery finds its way readily into the vein and does not become poured out into the tissues. Probably there is some amount of extravasation in all cases at first, but where owing to the reasons just given this is small in amount and can escape freely by the vein, no sac is formed, while if the amount of extravasation be large and the blood cannot readily find its way into the vein a sac results. In the popliteal vessels, or the femoral vessels in Hunter's canal, where the artery and vein are in close relation to one another and firmly bound together, an aneurysmal varix is more likely to be met with, while in Scarpa's triangle, where the vessels lie in loose areolar tissue, and in the subclavian vessels, where the vein and artery

are widely separated, the formation of an aneurysmal sac is much more probable.[1] In varicose aneurysms, as in other traumatic aneurysms, the sac tends to contract with prolonged rest, and may in some cases disappear.

Symptoms.—In aneurysmal varix a thrill and a murmur are constantly present. The thrill is fine, felt over a considerable area, and more plainly felt on light palpation. It may appear as early as the third day, but is often much later in making its appearance. In cases where the vein is exposed in the course of an operation the vibrations of its wall are sometimes visible. Accompanying the thrill is a murmur, which has been likened to the noise of machinery, and is often loud and widely conducted, and sometimes audible at a little distance from the patient. In arterio-venous communications in the neck the murmur sometimes annoys the patient at night when he lies on the injured side. The vein is distended where it communicates with the artery, but there is no general distension of the distal part of the vein, and no swelling or pain in the limb. In the course of years the artery tends to become dilated just above the communica-

[1] Makins, *loc. cit.*, p. 131.

tion with the vein. The volume of the pulse in the distal part of the affected artery is little if at all altered.

In varicose aneurysm there is, in addition to the above symptoms, which are common to both forms, a more or less definite tumour with expansile pulsation, indicating the presence of a sac. In some cases it may be very difficult to be certain as to the presence or absence of a sac. In a small proportion of cases the sac may shrink and disappear, but in the majority it tends to enlarge, and in time to rupture.

In both forms there is a well-marked effect on the general circulation, the pulse rate being permanently accelerated to 100 or more, in some cases as high as 140. This is probably a result of the rapid fall of the arterial blood pressure after each systole, from there being a direct communication with a vein, so that increased rapidity of the heart's action is necessary in order to keep up the blood pressure.

Treatment.—In all these cases early interference should be avoided. Complete and prolonged rest ought first to be tried, the patient being kept in bed and the part at perfect rest, splints being

applied if the lesion is in a limb. This gives time for the sac to contract, and for the circulation to become adapted to the new conditions. Aneurysmal varix usually needs no operative treatment, and it is not wise to interfere with these cases needlessly, as gangrene of the limb has been known to follow ligature of the affected vessels.

Varicose aneurysms can seldom be left alone. They tend to enlarge and eventually to rupture, and must be treated as must other traumatic aneurysms. Ligature of the artery close above and below the sac, leaving the vein untouched, is the method to be recommended when practicable. In the calf and forearm direct incision of the sac and ligature of the artery above and below the wounded point is suitable, and this method is suitable in the arm also. For femoral and popliteal varicose aneurysms ligature of the artery above and below without opening the sac is to be preferred.[1] In the neck the only method generally available is proximal ligature of the common carotid. But in the limbs proximal ligature is very likely to cause gangrene, and is to be avoided. In any case, the result of proximal ligature is merely to bring about

[1] Makins, *loc. cit.*, p. 150.

consolidation of the sac, thus converting a varicose aneurysm into the less serious aneurysmal varix, the communication between the artery and the vein remaining unaffected.

In South Africa, of fifteen cases in which proximal ligature was done in arteries of the limbs for arterio-venous communications, in no less than eight gangrene followed, and two of these died after amputation.[1] Three cases of ligature of the common carotid were successful. Nine cases of local ligature in arteries of the limbs were all successful except one, in which the superficial femoral was wounded so high up that the ligature could not be put on the wounded vessel, and the common femoral had to be tied, gangrene resulting. This case, therefore, can hardly be considered one of local ligature of the injured artery.

As illustrating the comparative infrequency of operations for wounds of vessels in modern warfare, the following figures are of interest[2]—

Bornhaupt, at Harbin, treated 3,600 wounded during 1904. 455 operations of all kinds were performed; of these only eighteen were operations

[1] See *Report on Surgical Cases, South Africa*, pp. 223–5.
[2] Follenfant, *loc. cit.*, p. 88.

on wounded vessels, four of these operations were for hæmorrhage,[1] five for traumatic aneurysms, and nine for arterio-venous aneurysms. Wounds of vessels thus formed only about 4 per cent. of the cases requiring operation. The same surgeon saw four aneurysms recover without operation.

[1] Probably *secondary*.

CHAPTER IV

WOUNDS OF NERVES

Cases of injury to large nerve trunks are more frequently seen with the small-bore bullet than used to be the case when the old forms of bullet were in use. This is owing to the greater frequency of concussion of nerves, from the high velocity and enormous energy of the modern bullet. Nerves, like vessels, may sometimes slip aside and so escape direct injury from the bullet, but a nerve though untouched by the bullet may still suffer severely from concussion, while a vessel receives no injury unless struck by a bullet or by a fragment of bone.

The primary gunshot injuries of nerves are *concussion, contusion,* and *partial* or *complete division.*

Secondary trouble may arise from implication of a nerve in a contracting scar, or in callus.

Concussion of nerves is a condition peculiar to gunshot wounds. The vibrations set up in the tissues by the passage of a bullet near a nerve so

affect the nerve fibres as to impair their conducting function, though the nerve is to all appearances quite uninjured, and has not been touched by the bullet. Thus in concussion of a nerve there is loss of function without any gross lesion. The vibrations are more intense, and the concussion effects more severe, when the velocity of the bullet is high, and when compact bone is struck; though it must be remembered that in cases of fracture accompanied by symptoms of nerve lesion, contusion or laceration of the nerve by fragments of bone cannot be excluded.

The severity of concussion varies greatly. In the slighter cases there is anæsthesia in the distribution of the affected nerve, lasting only a few days, and sometimes accompanied by tingling sensations in the part, with little or no interference with the motor functions of the nerve. In the most severe cases there is complete loss of function in the area of distribution of the nerve, with every sign of complete section, including the reaction of degeneration, wasting of the muscles, and trophic changes in the skin and its appendages. In these severe cases it is probable that the nerve-fibres, or most of them, degenerate below the site of the in-

jury, and must regenerate before the function of the nerve is restored. The fact that the connective tissue structure of the nerve is intact renders complete regeneration of the fibres easy, and recovery of function is usually complete. Sensation is the first to return ; motor power returns later. Severe concussion very closely simulates division of a nerve. In many such cases the nerve has been cut down upon and found to all appearance quite uninjured, and not directly in the track of the bullet. In cases of concussion the response of the muscles to electrical stimulation of the nerve trunk above the lesion is not always completely lost, and in these cases some of the fibres must have escaped degeneration.

All degrees of concussion are met with, from the slightest to the most severe, the intensity and duration of the symptoms varying accordingly.

In some cases concussion may at first affect several of the nerves of a limb, and in a few days all these, except one, which has been either more severely affected by concussion or perhaps divided, may recover their functions. Such cases are by no means uncommon in wounds in the neighbourhood of the brachial plexus.

After severe concussion of a nerve, recovery may be slower than after contusion or laceration by a bullet at low velocity.

Contusion of a nerve is often indistinguishable clinically from concussion, and is indeed often accompanied by concussion affecting the part of the nerve that has escaped actual contact with the bullet.

Contusion is produced by grazing contact of the bullet with the nerve, and in all but the slightest contusions some of the nerve-fibres must be ruptured, though the sheath of the nerve may not be torn. Hæmorrhage into the nerve often gives rise to symptoms of irritation, pain and hyperæsthesia, which appear early in the slighter degrees of contusion, but may be delayed till the sensory function of the nerve begins to return in more severe contusions, and may then last for a long time.

Partial division of nerves is common. In some cases nerves are perforated by the small-bore bullet, which appears to split the nerve rather than to cut its way through it, so that only a few of the nerve fibres are severed, and a bullet may perforate a nerve of smaller diameter than its own. Partial section of a nerve is more commonly a notch of

greater or less depth in the side of the nerve. Response to electrical stimuli is not completely lost in partial lesions, and the interference with the function of the nerve is not complete, unless the direct injury is complicated by concussion, which indeed is very often the case, and renders the diagnosis very difficult in such cases.

In partial injuries of a nerve, thickening may often be felt at the injured point after a time, if the nerve is superficial.

Complete division of a nerve by the small-bore bullet occurs when the whole width of the nerve is struck by the bullet, and very large trunks, as the great sciatic, can hardly be completely divided by an undeformed small-bore bullet. If the bullet strikes the nerve obliquely, it may destroy an inch or more of it. The well known symptoms of section of a nerve follow: anæsthesia and paralysis in the distribution of the nerve, loss of reaction of the muscles to the Faradic current within a few days, and later the reaction of degeneration, with defective circulation in the part and trophic changes in the skin, hair and nails. Complete division of a nerve is certain when there is total loss of response to electrical stimulation of

the nerve trunk, or later, if the bulbous end of the divided nerve can be felt.

Pain in injuries of nerves is sometimes severe, and may be referred to the distribution of the damaged nerve. Usually there is not much pain except at first, numbness following the early pain of the injury.

Diagnosis.—In the diagnosis of wounds of nerves the disturbing factor is concussion, as it is often impossible to decide how far the symptoms are due to concussion and how far to gross injury. If the loss of function is incomplete a partial lesion of the nerve is evident, but the difficult cases are those in which the signs are those of complete loss of function; and in such cases it is often impossible to determine whether the nerve is divided, or severely concussed, or partly divided and suffering from concussion as well. In this connection the range at which the injury was received may afford some help, as at a long range the bullet has not sufficient energy to produce a severe degree of concussion, and the symptoms are likely to be due to actual division of the nerve. The same reasoning applies when the bullet has lodged without striking bone, this being evidence that its energy was nearly

spent when it struck. If some response to electrical excitation of the nerve above the lesion still remains, this indicates either concussion or incomplete division of the nerve.

Many of these doubtful cases are cleared up as time elapses. The effects of concussion, except in the most severe degrees, begin to pass off more or less rapidly, and early improvement makes it clear that the nerve has at any rate not been divided. But after severe concussion, causing degeneration of the nerve fibres, improvement may be so long delayed that the diagnosis from division cannot be made with certainty without exploration, unless a bulbous end can be felt through the skin.

The **prognosis** as regards recovery of function is good in concussion, as the sheath and framework of the nerve are intact, and complete recovery may be expected, though it may be very slow. After complete division of a nerve, recovery is prevented by separation of the divided ends, and by their being involved in the cicatrix of the wound. The prognosis is not good unless the ends are sutured. After partial lesions recovery is often incomplete.

Treatment.—Asepsis of the wound is important, as suppuration increases the likelihood of

neuritis, and causes greater danger of trouble from contraction of the cicatrix. In addition to taking every precaution to prevent infection of the wound, the part should be kept at perfect rest on a splint, and should be in such a position as to relax the injured nerve. Light massage and passive movements should be begun as soon as they can be borne, and the nutrition of the muscles should be kept up by means of stimulation with the constant current. Care must be taken to prevent any of the joints becoming stiff, and this is especially necessary in paralysis of the leg, where troublesome shortening of the calf muscles will occur if not prevented, and may necessitate division of the tendo Achillis later.

The question of operation for nerve-suture often arises. If there is no doubt that the nerve is divided; if, for instance, it is seen in the course of an operation for hæmorrhage or for a fracture, it may be sutured at once. In any case where there is any doubt as to the exact nature of the lesion, operation should not be undertaken hastily. The symptoms may be due chiefly or entirely to concussion, in which case there is no need to operate, and recovery will usually take place in time. It has frequently happened that on exposing a nerve

believed to be divided it has been found intact. Another objection to early operation is that if the nerve be found severed and be sutured, the contraction of the cicatrix of the bullet wound may interfere with the success of the suture. Suppuration in the bullet wound of course puts nerve suture out of the question as long as the septic condition lasts. It is better to wait at least two months in these doubtful cases, and if at the end of that time there is no improvement in the symptoms, the nerve may then be cut down upon, provided that the original wound has healed and that there are no septic sinuses. It is not necessary here to give the details of the operations of nerve suture or nerve grafting, or of the after treatment. The results of suture are encouraging, though recovery may take a long time.

Secondary involvement of a nerve in scar tissue or in callus is not uncommon. It gives rise to gradually increasing loss of function, with pain and tenderness both at the compressed point in the nerve and in its distribution. It is seldom that the affected nerve has altogether escaped primary injury; as a rule there has been some degree of injury to it from the first. The treatment

is to free the nerve from the compression, stretch it, and make a fresh bed for it, as if it is replaced in its old bed it may again become compressed.

In rare cases nerves may be irritated by fragments of bone or small pieces of a broken up bullet or other foreign body. These can be detected and localised by means of X-rays, and removed.

Traumatic neuritis is a common complication of gunshot injuries of nerves, especially of contusion and incomplete section. In some cases the neuritis may spread and involve the trunk of the nerve far above the lesion.

The symptoms due to wounds of nerves are sometimes imitated by functional symptoms, often very striking. These are sometimes the result of nervous shock, as from the explosion of a shell close to the patient. The character of these symptoms makes their nature clear.

The musculo-spiral nerve is more frequently injured than any other, owing to its long course and close relation with the humerus. It is also more often implicated in callus than any other nerve.

Certain nerves seem to be more susceptible to injury than others, or to suffer more severely than other nerves from slight traumatism, and to recover

less easily.[1] The posterior interosseous in the fore-arm, and the external popliteal or peroneal in the lower limb, are especially vulnerable, and after a lesion of the main trunk of the musculo-spiral or great sciatic it often happens that these vulnerable branches are more profoundly affected and recover more slowly than the rest of the nerve, and in some cases they remain permanently paralysed after the other branches of the main trunk have recovered, a point of some importance in prognosis.

[1] Makins, *loc. cit.*, p. 361.

CHAPTER V

FRACTURES

Fractures of the long bones form a considerable proportion of gunshot injuries, and are always serious. Practically every gunshot fracture is compound, the only exceptions being the very rare cases of simple fracture produced by large fragments of shell that do not penetrate deeply. In the great majority of cases there is some comminution, which is often very severe; and the fracture may be complicated by various degrees of injury to the soft parts—vessels, nerves, muscles and tendons, and skin. The external wounds vary from the normal small punctures to the most severe "explosive" effects. The nature and degree of the injury to a bone depend on the energy of the bullet and the resistance offered by the bone, the latter being the more important of these factors. This is evident on comparing the injuries met with in compact and cancellous bone, the usual injury in the compact shaft of a long bone being comminution, while in

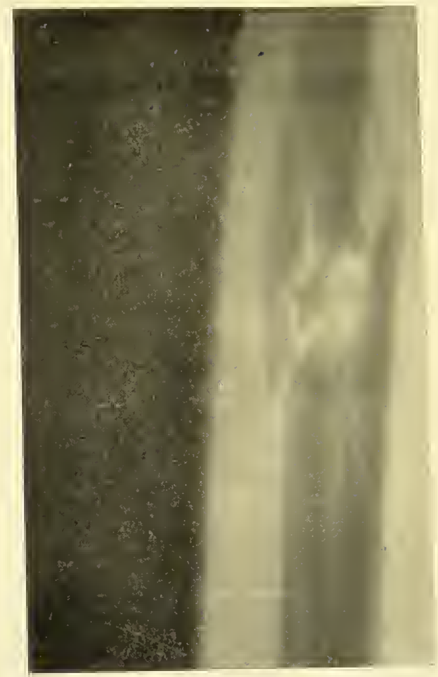
the cancellous articular end perforation or grooving more commonly occurs. The size of the bullet also has some influence on the amount of fissuring, larger bullets exerting greater wedge action and tending to split the bone more extensively. The angle of impact of the bullet upon the bone affects the nature of the injury. As a rule, the more perpendi-eularly the bullet strikes, and the nearer to the centre line of the shaft, the greater is the damage. Oblique impaet tends to cause the line of fraeture to be oblique, often with extensive fissuring. When the bullet passes along the long axis of a bone it may eomminute it in almost its entire length, though in one ease in South Afriea a Mauser bullet passed from above along the whole length of the medullary eanal of the tibia, producing only a slightly fissured fracture at the narrowest part of the bone.[1]

The small-bore bullet most eommonly produees comminuted fractures of the shafts of long bones. The primary type of these fractures is the **stel-late** form [2] (Fig. 11, A; and Plates II; V, B; and VI, B). In this the bullet perforates the bone

[1] *Report on Surgical Cases, South African War*. Fig. 63, p. 196, T.

[2] Makins, *loc. cit.*, p. 161.

A



B

PLATE II.

A. Typical stellate fracture of the Ulna.
B. Stellate fracture of the Fibula.

[*To face page* 100.

centrally, and from the bullet track four oblique fissures radiate to the surfaces of the bone, separating a wedge-shaped fragment on each side, and causing the ends of the main fragments to be pointed. This type of fracture has been frequently described as "butterfly." From the suppression of some of

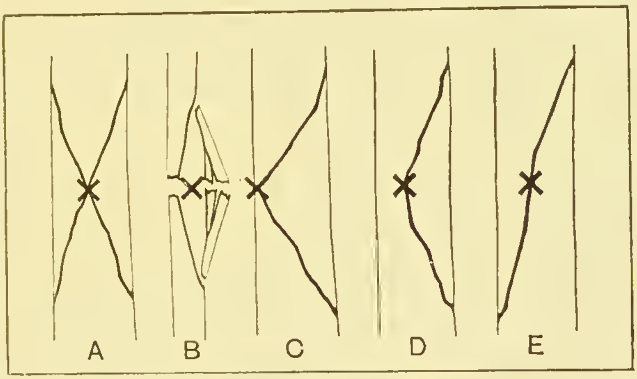


FIG. 11.—Five Types of Fracture.

A. Primary lines of stellate fracture; wedges driven out laterally and pointed extremities left to main fragments. B. Development of same lines by a bullet travelling at a low degree of velocity; suppression of two left-hand limbs and substitution of a transverse line of fracture; a spurious form of perforation. C. Typical complete wedge. D. Incomplete wedge; impact of bullet, lateral or oblique, and two left-hand lines seen in A are suppressed. E. Oblique single line, one right and one left hand line seen in A, suppressed. The influence of leverage from weight of the body probably acts here. (Makins.)

these fissures modifications in the type of fracture arise. Thus, if both the fissures on one side are suppressed, the wedge form of fracture is the result (Fig. 11, C, D; and Plates VII and IX); while suppression of the ascending fissure on one side and of the descending fissure on the other side gives

an oblique fracture (Fig. 11, E; and Plate IV). This form of oblique fracture is rare, and is probably due to the bone being in a state of strain from the weight of the body at the moment it is struck. It is very seldom seen in the upper limb. The other form of oblique fracture, from oblique impact of the bullet, is commoner.

Examination of a large number of skiagrams of gunshot fractures shows that most of them can be referred to the stellate type or one of its modifications, though there is often much comminution, the lateral wedges being further broken up into numerous smaller fragments and the main fragments fissured and broken. Still, in a very large proportion of even highly comminuted fractures the type to which the fracture belongs can be recognised, if the skiagram has been taken with the X-rays directed parallel to the course of the bullet. Skiagrams taken in other directions do not reveal the type of the injury. This is, perhaps, a matter of academic rather than practical interest. At low velocities the fissures sometimes run irregularly, tending to be more nearly transverse, as in Fig. 11, B.

From a clinical standpoint fractures may be

divided into three classes, according to their severity, which depends, in fractures from the small-bore bullet, on the range at which they are produced.[1]

(1) In the **short range** class, received at ranges of 200 yards or less, the damage to the bone is greatest. The entrance wound is small and typical. The exit wound is large, irregular, and its edges are often ragged. The comminution of the bone is very great, there may be dozens of fragments, mostly of small size, and these fragments are driven onwards as secondary missiles, and produce much laceration of the soft parts. If the bone is not well covered many of the fragments are driven out on the exit side, and an "explosive" exit wound results. Where the bone is covered by thick muscles, as in the thigh, only a few of the fragments reach the surface, and the exit wound is smaller; but the "explosive" effect, though not so apparent, is still produced, there is a lacerated cavity in the muscles, filled with clot, torn muscle, and fragments of bone. The cavity is more or less conical in shape, the apex being at the point where the bullet struck the bone. The bullet is often broken up, and fragments of lead and of the torn and split

[1] Hickson, *Report on Surgical Cases, South Africa*, p. 170.

envelope are mingled with the bone débris. There is a considerable gap between the ends of the main fragments, from the amount of comminution and displacement of the comminuted portions, and this gap may be two or three inches in extent. Fissures run up and down the bone, often splitting off long fragments. In rare cases the shaft of the bone may be fractured again at some little distance from the point struck, from the violence of impact of the bullet (Plate III, B). In these very severe fractures the wounds frequently suppurate, on account of the great difficulty in preventing infection of the lacerated soft parts, and the large amount of oozing and serous discharge that must occur.

(2) Fractures of the **medium range** class, received at ranges of 300 to 800 yards, are of less severity than those just described, owing to the lessened velocity of the bullet. The exit wound is still markedly larger than the entrance, but explosive exit wounds are not seen. There is much less laceration of the soft parts, and though the bone is still a good deal comminuted, the fragments are larger, less numerous, and not so much displaced. Fractures in which the stellate type is easily traceable are common at these ranges.

A

B

PLATE III.

A. Comminution of the Radius (Stevenson).
B. Fracture of the Radius near its lower end, with many fragments of the broken-up bullet and a second fracture higher up.

[*To face page* 104.

(3) The **long range** class includes fractures reeeived at ranges of 900 yards and upwards. The severity of the injury diminishes as the range inereases. The exit wounds are smaller, and at the longer ranges the exit wound may be of the same size as the entranee. There is little damage to the soft parts, and the eomminution of the bone is less, the fragments being few and of large size, and sometimes not eompletely separated. Fraetures of the wedge type are often seen at these long ranges. The bullet more frequently lodges. Infection of the wound is mueh less likely to oeeur. At extremely long ranges the bullet may make lateral or irregular impaet, and will then produee a large and irregular entranee wound, and more severe comminution of the bone.

The displaeement of the fragments in all eomminuted fractures is ehiefly towards the exit side, in lines radiating from the point of impaet of the bullet upon the bone, this displaeement being due to the propulsive effeet of the blow from the bullet. There is also some displaeement in a lateral direetion, away from the bullet traek, eaused by the wedge aetion of the bullet as it traverses the bone. Small fragments of bone and of the bullet may re-

bound from the point of impact and lie on the entrance side.

The fissures produeed by the small-bore bullet often run a long way up and down the shaft; but owing to the small diameter of the bullet these

FIG. 12.—Oblique perforation. Large fragment detached at exit aperture. Caused by a bullet travelling at a low rate of velocity. The dotted lines indicate the course of the track. (Makins.)

fissures seldom extend into the neighbouring joints; they mostly stop at the cancellous ends of the bone, and do not communicate with the joint. The periosteum over the fissures is sometimes not torn.

Perforation of a bone by the small-bore bullet is rare in the shaft, though it is the common form of injury in the cancellous ends at all ranges. It is more often seen in the shaft at medium and long ranges, though exceptionally clean perforation of the shaft may be met with at quite a short range.

Fig. 13.—Perforation of lower third of Tibia, showing lifting and fissuring of the compact roof of the tunnel. (Makins.)

As the bullet pierces the bone, it generally splits off a piece from the surface at the exit side (Fig. 12). In these cases of perforation there may be no solution of continuity of the bone, or in some cases one or two nearly transverse fissures may run from the perforation to the surfaces of the bone, completing

the fracture. If the perforation is near one of the surfaces of the bone, the roof of the tunnel may be raised and broken by the wedge action of the bullet (Fig. 13).

Gutters, grooves, and notches may be looked upon as incomplete perforations, the roof of the tunnel being missing. They are common in the articular ends, but are seldom seen in the shaft.

The larger forms of bullet produce injuries very similar in type to those caused by the small-bore bullet, but on a coarser scale. Perforations are less often seen, but may occur. The fine comminution so typical of fractures from the small-bore bullet is not seen in injuries from these large missiles, the fragments being larger, owing to the lower velocity and smaller energy of the bullet. The greater size of the bullet causes it to exert more wedge action, and so there is more extensive fissuring, and the fissures have a marked tendency to run on into the neighbouring joints. This is of some importance, as if the wound becomes septic infection may spread by means of the fissures into the joint.

Contusion of a bone without fracture is rarely

A

B

PLATE IV.

A. Oblique fracture of the Femur with slight comminution and much displacement.
B. Oblique fracture of the Tibia showing a tendency to spiral fissuring.

[To face page 108.

seen nowadays, though it occurred often enough with the old spherical bullet. It may be due to a spent bullet that has not enough remaining energy to fracture the bone, or in some cases it may occur when a bullet makes glancing contact with a bone. The result is usually necrosis of a superficial scale of bone, and if the wound is septic osteomyelitis may occur.

A small-bore bullet just grazing a bone has been known to produce a transverse fracture.[1] This, however, is a very rare accident.

The articular ends of long bones, consisting of cancellous bone with a thin compact surface layer, are usually cleanly perforated by the small-bore bullet. Those that are denser in structure, having to bear the weight of the body, are sometimes broken up, the upper end of the femur and the lower end of the tibia affording instances of this. The smaller articular ends, as those of the radius and the ulna, are usually considerably comminuted, their small size making clean perforation less common. The larger bullets may perforate the larger articular ends, as those in the knee-joint, at long ranges, but at short ranges break them up into

[1] Stevenson, *loc. cit.*, p. 294, and Fig. 16.

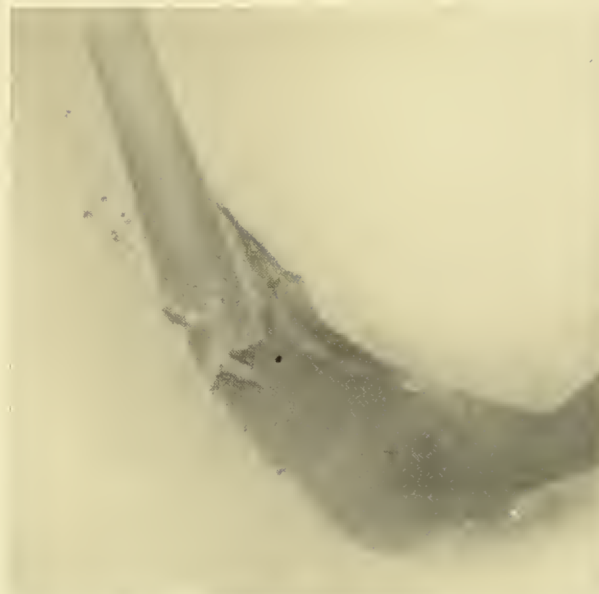
many fragments. The destruction produced in the articular ends of bones by large bullets at short ranges is very severe.

The short bones of the carpus and tarsus are very similar in structure to the articular ends of the long bones, and receive similar injuries, being usually cleanly perforated by small-bore bullets, comminuted and crushed by the Martini-Henry and other large bullets. They may be comminuted by small-bore bullets if the bullet makes irregular impact, or has been deformed by ricochet.

Symptoms and Course.—Perforations and grooves, where there is no loss of the continuity of the bone, may be diagnosed from the line the bullet has taken, and there may be some bone dust or débris in the exit wound. The size of the exit wound is not of any assistance in these cases, as there is no enlargement of it through fragments being carried out with the bullet. Sometimes by external palpation a groove or notch in the bone may be felt. The wound must not be explored or probed in any way. X-rays may fail to show a perforation, unless they are directed so that the course of the rays follows that of the bullet.

In fractures there are the usual signs. Owing

A



B

PLATE V.

A. Stellate fracture of the Radius.
B. Stellate fracture of the Humerus.

[*To face page* 110.

to paralysis of the muscles from local shock there is often little or no shortening at first, and pain may be slight from the effects of local shock on the nerve-endings. In highly comminuted fractures abnormal mobility at the site of fracture is very marked, and in these cases crepitus may be hard to elicit, from the ends of the bone being widely separated and the small fragments embedded in muscular tissue and clot. Exact and complete information as to the nature of the injury can be obtained from skiagrams, and it is of importance to obtain good skiagrams, and to take two views of the part in planes at right angles to one another. Stereoscopic skiagrams are also very valuable.

In cases that remain aseptic union is often slow, a large mass of callus is thrown out round the numerous fragments, and this takes a long time to consolidate. The track in the soft parts often heals slowly on the exit side, owing to the amount of contusion of the tissues by the bullet and fragments of bone, which sometimes causes small pieces of tissue to necrose, and these are slow to separate in an aseptic wound. Late necrosis of small fragments of bone may give trouble weeks or months after the external wounds have healed, often on beginning

to use the limb again. These small fragments probably lose their vitality at the time of the injury, but cause no irritation until active movement is resumed.

Septic cases are far more serious and troublesome. Unfortunately, infection of the wound occurs in a considerable proportion of gunshot fractures, from the want of early skilled assistanee, the necessity of transport, and from the nature of the wounds when these are large and lacerated. In the severely comminuted fractures of the short range class, with large exit wounds and much laceration of the soft parts, it is exceptional for the wound to escape infeetion. Though infection is so common, it is generally of a mild type; at least, this was the case in both South Afriea and Manchuria. Comparatively few of the patients with suppurating compound fractures suffered mueh constitutional disturbance, and the more dangerous septic eomplieations were remarkably infrequent. Infection in fractures leads to necrosis of the fragments, prolonged suppuration, and the formation of troublesome sinuses. In many cases exhaustion from prolonged suppuration and toxæmia (often called "septicæmia") result, and more rarely osteomyelitis, sometimes pyæmia.

A

B

Plate VI.

A. Severely comminuted fracture of the Tibia and Fibula.
B. Stellate fracture of the 2nd Metacarpal.

[*To face page* 112.

Secondary hæmorrhage is not an uncommon complication. Failure of union is not often seen.

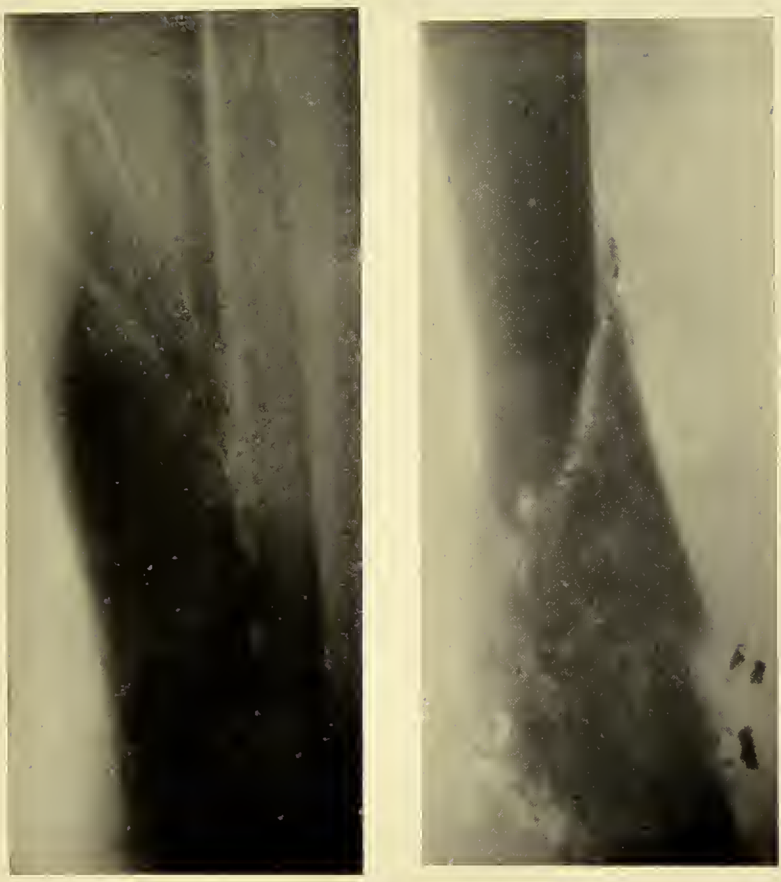
The mortality in gunshot fractures is not high. In 2,845 cases of fracture treated at Harbin in 1904 there were only 39 deaths (1·37 per cent.), and of these 16 occurred in 478 fractures of the femur.[1] In South Africa 1,306 fractures occurred, with 73 deaths (5·6 per cent.). Of these 439 were fractures of the femur, with 50 deaths. The prognosis depends chiefly upon whether the wound is aseptic or not, and on the amount of damage to the soft parts, especially the vessels and nerves. The most severely comminuted fracture, if aseptic, provided that the limb is not damaged beyond recovery, is less serious than a comparatively slight injury to the bone with infection of the wound.

In the **treatment** of gunshot fractures, the most important point is to secure asepsis of the wound, if possible, by immediate application of the first field dressing, followed by thorough cleansing and disinfection of the surrounding skin as soon as possible, with careful dressing of the external wounds. Hæmorrhage must be treated on the lines described in a previous chapter, and on no account should

[1] Follenfant, *loc. cit.*, p. 89.

plugging of the wound be resorted to, as this always leads to infection, often of a severe type. Tight application of splints or bandages must also be carefully avoided. Immobilisation of the limb is difficult, as the patient has to be moved to a fixed hospital, and the limb must be so fixed as to suffer as little disturbance as possible on the journey. The effects of transport are very bad, especially in fractures of the lower limb, and the length of the journey should be reduced as much as circumstances allow. The methods of immobilising the various fractures will be dealt with later, when fractures of the individual bones are being considered.

Exploration of the wound and removal of fragments is necessary in certain cases. It is done as part of the treatment, not for diagnosis as the term "exploration" suggests, and should not be undertaken until the patient has reached a fixed hospital. The object of this procedure is to remove fragments of bone that are likely to necrose and prevent healing. Exploration must, of course, be done with every precaution as regards asepsis. All septic comminuted fractures require exploration; the exit wound must be opened up, and all fragments that are loose and completely detached from the periosteum



A *B*

PLATE VII.

A. Wedge fracture of the Tibia with upward fissuring of the shaft.
B. Comminution of the Femur.

[*To face page* 114.

removed, leaving *in situ* larger fragments that are not completely detached. If this is not done, or if it is done imperfectly, these small fragments necrose and give endless trouble; they keep sinuses open for months or years, and require repeated operations for their removal. They can easily be found and removed within a short time of the receipt of the injury, but once the callus surrounding them has become consolidated they are very difficult to find, and the last of them may only be got rid of after a long series of troublesome operations. During and after the South African war numbers of cases came to Netley with sinuses leading to sequestra embedded in the callus of united fractures, and even at the present time, more than five years after the end of the war, cases of the same kind are still met with from time to time. Thorough exploration and removal of all loose fragments at first would have saved most of these patients much suffering, and shortened their convalescence. After exploration of a septic fracture, free drainage must be provided, either through the exit wound or by a counter-opening suitably placed.

In aseptic cases exploration is very seldom needed. Most aseptic fractures recover perfectly and cause

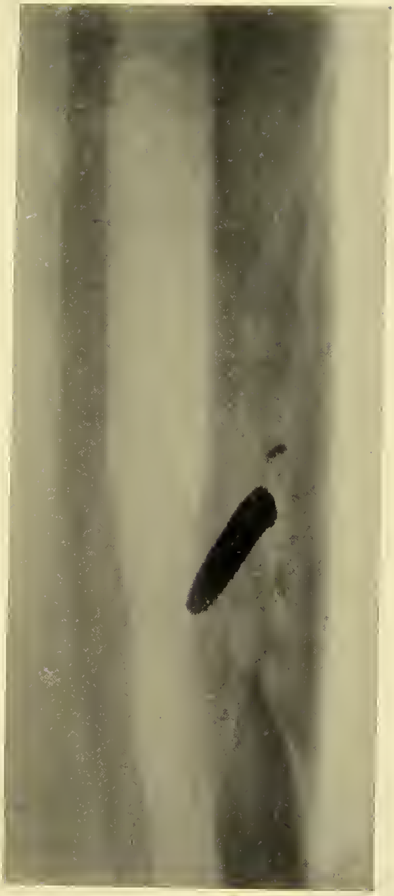
no later trouble. In some cases with severe comminution some of the smaller fragments have their vitality destroyed, and these cause irritation later, so that in cases with severe comminution and with large or "explosive" exit wounds it is better to explore and remove small and completely detached fragments.

Operative fixation of gunshot fractures by screws, pegs, or wire is very seldom needed in the early stage of treatment. It is hardly practicable in badly comminuted fractures, and is only suitable for oblique fractures, and then is not necessary unless good position cannot be maintained by other means. Later, in the event of non-union, operations for screwing or wiring the bones may be required after all suppuration has ceased and the wounds are soundly healed.

Amputation is very seldom required for gunshot fractures at the present time, though formerly it was done freely. In Manchuria, in the Russian army in 1904, amputation was done in only 0·5 per cent. of all wounds, and the proportion of amputations during the whole war (on the Russian side) was slightly over 1 per cent., including amputations of the fingers.[1]

[1] Follenfant, *loc. cit.*, p. 89.

A



B

PLATE VIII.

A. Fracture of the Radius.

B. Fracture of the Tibia and Fibula, with lodgment of a slightly deformed Mauser bullet.

[*To face page* 116.

Primary amputation is not often necessary, and the necessity for it depends not on the degree of injury to the bone, but on the amount of damage to the soft parts. In cases where a limb is carried away, or there is very extensive destruction of the skin and muscles from a shell wound, amputation is necessary, and often amounts to little more than trimming the lacerated tissues and bringing them together. Injury to the main vessels of a limb complicating a fracture does not always necessitate amputation; if gangrene does not result the limb may be saved. Injury to the main nerves does not render amputation necessary, the limb can be saved; though if the function of the nerves does not become restored the limb may be useless, and amputation may be needed later. Even in cases of injury to both the vessels and the nerves amputation is not generally necessary. Where two fractures occur in the same limb, as in the arm and forearm, or the thigh and leg, each injury must be considered by itself in deciding whether amputation is necessary; the fact of there being a second fracture in the lower segment of the limb does not justify amputation for a fracture that would not of itself require it.

Primary amputation means amputation on the

field or in the field ambulance, under the most adverse conditions as regards aseptic work, and with the prospect of a journey before the patient almost immediately after the operation. Under these circumstances it is not to be wondered at that primary amputations do badly, owing chiefly to the necessity of transporting the patients ; the wounds become septic, the flaps often slough, osteomyelitis occurs in the stump, and secondary hæmorrhage is of frequent occurrence. If the patient survives, re-amputation is often needed. It is better, therefore, to avoid amputating in the field ambulance if it is possible to do so without unduly risking the life of the patient. The injured limb may be wrapped in a large amount of dressing, and the amputation postponed till the patient arrives at the nearest fixed hospital.

Intermediate amputations, done in the acute stage of septic inflammation, are always dangerous, and should be avoided if possible. They are only needed in some cases of very acute infection, where it is necessary to get rid of the septic focus at once, as in cases of malignant œdema, or for gangrene, or rarely for secondary hæmorrhage.

Secondary amputations form by far the greater

proportion of amputations for gunshot wounds. They may be required for gangrene, occasionally for secondary hæmorrhage, most commonly for exhaustion from prolonged suppuration (commonly spoken of as "septicæmia"), and sometimes on account of osteomyelitis and necrosis of the fractured bone. Sometimes amputation is required at a later date, when a limb is useless from extreme destruction of bone and non-union, resulting in a flail limb, and in some cases a limb that is useless and painful from nerve injuries has to be removed.

The common indications for amputation in gunshot wounds are severe shell injuries damaging a limb beyond hope of recovery, gangrene from any cause, and "septicæmia" (so-called). Amputation for any other cause, as hæmorrhage, is very rare. In amputating for osteomyelitis it is important to remove the whole of the affected bone, otherwise the infective process is very likely to recur in the stump, if any portion of the bone be left.

Gunshot fractures of the **scapula** are seldom of much importance. The body of the bone is often perforated, the chest being commonly wounded at the same time. In such a case there are usually no special signs of the injury to the scapula, even

pain or limitation of movement being slight or absent, and no treatment beyond keeping the part at rest is required. Similar perforations of the spine of the scapula are met with in longitudinal wounds of the back, and in these also the injury is of little importance. Bullets not infrequently lodge in the muscles about the scapula, but seldom give rise to any inconvenience. The acromion or coracoid process, if hit, is generally comminuted. Injuries to the head of the scapula will be dealt with under wounds of the shoulder joint.

The **clavicle** may be perforated, especially at the ends, but is more frequently comminuted, every variety of comminuted fracture being met with. The large amount of callus formed in the healing of gunshot fractures is very obvious in the clavicle, from its superficial position.

The **humerus** is very frequently injured. Every variety of injury is met with. Perforation or grooving of the upper end of the humerus about the great tuberosity is not uncommon. Perforation may occur in the shaft, which is, however, much more often comminuted. At short ranges, "explosive" effects are well marked. Musculo-spiral paralysis is a fairly common complication, the nerve

being seldom divided but generally concussed or contused, or later involved in callus. In a series of 83 cases of fracture of the humerus reported from South Africa, musculo-spiral paralysis occurred in 12 cases.[1]

The number of fractures of the humerus in the South African war was 306, with 9 deaths (3 per cent.).

In the **forearm,** fracture of one bone is much more common than fracture of both. All varieties of fracture occur. "Explosive" effects are often seen, especially in fractures of the ulna, which is subcutaneous in its whole length. Perforations are more common about the upper end of the ulna and the lower end of the radius. The large amount of callus formed often interferes with pronation and supination after fracture of one or both bones.

Sixty-five fractures of the radius were reported from South Africa, 44 of the ulna, and 50 of both bones. There was only one death, after a fracture of the ulna.

The **metacarpal** bones are generally much comminuted, and the bullet often breaks up on these small hard bones. In many cases several of the

[1] *Report on Surgical Cases, South Africa*, p. 190.

bones are hit. Even in such small bones as the metacarpals and phalanges clean perforations are sometimes seen, usually at or near one end.

The **treatment** of gunshot fractures in the upper limb demands no very special notice, as it is carried out in accordance with the principles already detailed. Ordinary straight and angular splints serve well for immobilising the broken bones. Cardboard splints are very useful, being light, easily shaped to the limb, and less likely to become displaced than wooden splints. In the new field fracture box sheets of compressed "fibre" are supplied as a substitute for cardboard, and are more rigid than cardboard, as well as being unaffected by moisture. The aluminium field splints supplied are also very suitable for all fractures in the upper limb, any desired pattern of splint being readily made in a few minutes from the materials supplied. The Russians in the late war made great use of cardboard splints fixed with starched bandages, and the Japanese used splints made from the long millet stalks (*kaoliang*, the same as the Indian *jowari*), found in abundance in the country. It is most important to avoid tight application of any splints or bandages in fractures of the upper limb, on account

of the danger of gangrene occurring from swelling of the limb beneath the bandages, which may be overlooked if the patient has passed out of the hands of the surgeon by whom the splints were applied. In some fractures of the humerus Stromeyer's cushion, which was devised on account of the danger of applying any tight apparatus in these cases, may be useful.

Gunshot injuries of the **pelvic bones** are of comparatively little importance in themselves, the accompanying injuries to the pelvic organs being far more serious. Usually the damage to the bone takes the form of a perforation or groove, though a bullet passing in the plane of the expanded portion of the ilium may produce some comminution. The sacrum is usually perforated. The rami of the pubis and ischium are sometimes comminuted, but the continuity of the pelvic girdle is seldom interrupted as in ordinary fractures of the pelvis, and injury to the bladder or urethra from laceration by the broken bone is not common, though these structures may be wounded by the bullet.

The **femur** is one of the most frequently fractured of all long bones. Fractures of the femur are the most serious and dangerous of all gunshot fractures, and present the greatest difficulties in

treatment under the conditions of active service. It is especially difficult to immobilise the limb satisfactorily for transport, and moving the cases causes great suffering to the patients and interferes materially with their chances of recovery. It is often very difficult to keep the wounds aseptic, especially when there is severe damage to the soft parts, and when the external wounds are in the neighbourhood of the perineum. Some of the worst cases of wound infection seen in South Africa were in fractures of the femur.

The femur is a very dense and resistant bone, hence comminution at short ranges is very severe, and damage to the main vessels and nerves correspondingly frequent. Every variety of fracture is met with. Perforation of the shaft is uncommon, except towards the lower end, where the shaft expands. Although comminution is often very extensive, "explosive" exit wounds are not seen, as the covering of soft parts is so thick that few of the fragments reach the surface; and though there is great laceration in the muscles the exit wound is seldom of greater diameter than an inch or an inch and a half. These fractures are accompanied by much shock, and local shock is also well marked in the limb.

PLATE IX.

Wedge fracture of the Tibia.

[To face page 124.

Treatment is carried out on the lines already laid down. The greatest difficulty, next to preventing infection of the wound, is fixation of the fractured bone. For transport the best that can be done is to apply a long external splint, making extension by means of a perineal band, and use short splints or plaster-of-Paris to support the broken ends. On reaching a fixed hospital the perineal band must be got rid of, and if the case is suitable for treatment on a long splint weight extension should be used, care being taken not to use too much extension at first, and to increase the weight as the muscles recover their tone. Skiagrams should be taken to make sure that the position is good. But by far the best method of treatment is by means of Hodgen's splint, especially for fractures near the upper or lower end of the bone. Hodgen's splint is far more comfortable for the patient; it allows of some movement of the body without disturbing the fracture, it gives flexion of the hip and knee joints, and so overcomes the tendency to angular deformity in fractures near those joints, and the wounds are easily got at for dressing, with little disturbance of the splint or the patient. The amount of extension is easily adjusted, and the splint acts just as

efficiently if the patient is lying on the ground as if he is in a bed. The result in cases of fracture of the femur depends largely on the skill and care with which the treatment is carried out; in some cases of very severe destruction of the bone union has been got with only very slight shortening. In some cases zinc or wire netting splints are useful; they can be sterilised and incorporated in the dressings. The aluminium field splint is of no use for fractures of the femur, it is not sufficiently rigid, and no pattern has yet been devised that will fix the hip joint. As soon as the fracture has consolidated sufficiently, a plaster case may be applied and the patient allowed to get about.

In South Africa 439 fractures of the femur occurred, with 50 deaths (11·4 per cent.).

The **patella** is usually perforated, with wound of the knee joint. It may be fractured transversely by a bullet crossing it from side to side. Grooves are often met with. Stellate fractures, such as those produced by direct blows on the patella, are very rarely seen in gunshot injuries. No special treatment is necessary, unless there is a transverse fracture with much separation, when wiring will be required, but as a rule there is little or no separation.

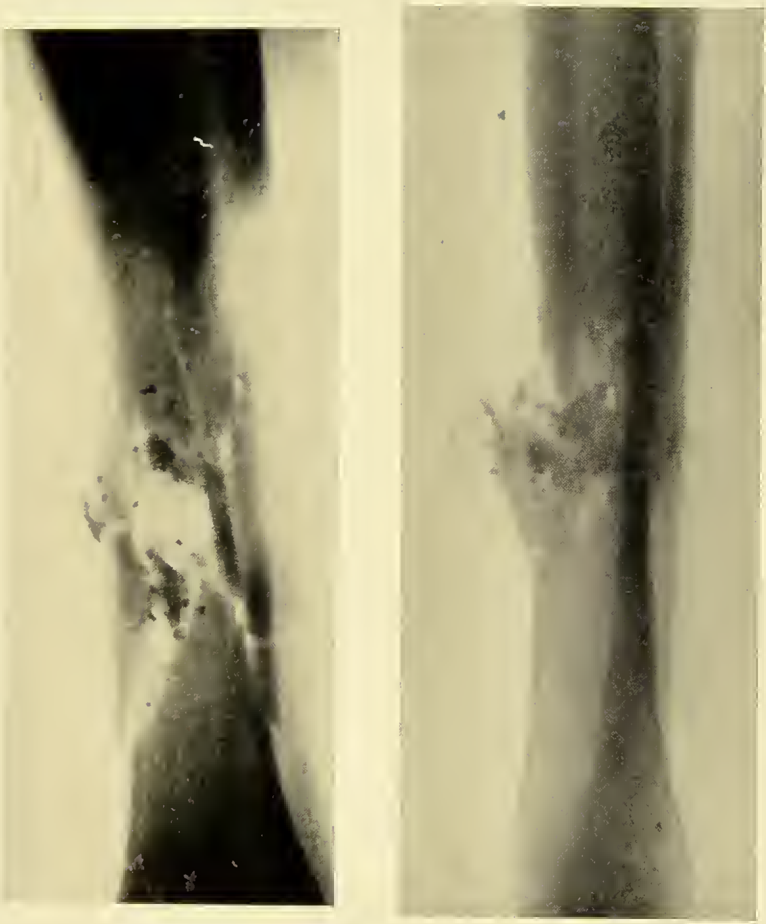


PLATE X.

Two comminuted fractures of the Tibia. In the left-hand figure (from Stevenson) the stellate type of fracture is distinctly traceable.

[*To face page* 126.

In the leg the **tibia** is frequently severely comminuted, and owing to its superficial position explosive wounds are common. Perforation is not uncommon about the upper end of the bone, and in exceptional cases may occur in the shaft. At medium and long ranges the wedge type of fracture is often seen.

Fractures of **both bones** of the leg are severe and troublesome injuries, the wounds often become septic, and though there is not any very great danger to life, amputation has to be performed in a considerable proportion of the cases. Fractures of the tibia alone are less serious, and both infection of the wound and loss of the limb less frequently result. Fractures of the upper end of the tibia are rather liable to fissure into the knee joint, and those of the lower end into the ankle joint. The fibula alone is seldom fractured, and the injury is not of great importance. In all fractures of the leg bones injury to the vessels is common, and the nerves being in close relation to the vessels are often injured as well. Secondary hæmorrhage is a fairly common complication, the wounds being so often septic.

In the treatment of these fractures any splints that will keep the fragments in good position may

be used; usually a back splint with a foot-piece and two side splints, or the aluminium field splint. Croft's plaster splints are very useful.

In South Africa there were 107 fractures of both bones of the leg, with 10 deaths (9·4 per cent.); 172 of the tibia alone, with no death; and 40 of the fibula alone, with no death.

Fractures of the **metatarsal** bones are similar in character to those of the metacarpals, and owing to the injury being inflicted through the boot and sock, and to the generally dirty condition of these and of the skin, the wounds are almost invariably infected. Pus tends to burrow in the sole, and the results of the injuries are often serious, the foot being permanently weak and painful, and of little use. Wounds from ricochet bullets are common in the foot and leg. Accidental wounds of the foot, often self-inflicted, are not uncommon.

The only **tarsal** bone that is at all liable to be wounded without injury to any joint is the os calcis, which is exposed as men lie behind cover, and the injuries are seldom serious, being usually perforations or grooves. Injuries to the other bones of the tarsus belong more properly to the category of wounds of joints.

A B

PLATE XI.

A. Comminution of the 1st and 2nd Metatarsals.

B. Comminution of the bases of all the metatarsals, and of the distal tarsal bones, with lodgment of the bullet in the internal cuneiform and 1st metatarsal; the latter being extensively fissured.

[*To face page* 128.

CHAPTER VI

WOUNDS OF JOINTS

GUNSHOT wounds of the larger joints were formerly very severe and fatal injurics, owing to the great damage done to the articular ends of the bones by the large bullets then in use, and still more to the almost invariable infection of the wound, which was brought about by the exploration with an uncleansed finger recommended by all military surgeons in the pre-antiseptic era. Primary amputation or excision was then the rule, lodgment of the bullet in the joint was common, and the mortality was very high. It was in wounds of the knee-joint that the modern system of wound treatment, based on avoidance of interference and prevention of infection, first gained marked success, in the well-known work of Reyher and von Bergmann in the Russo-Turkish war of 1877.

Under presont day conditions these injuries are much less serious; the small-bore bullet inflicts

9

comparatively slight damage on the ends of the bones, causing perforation or grooving as a rule, seldom comminution, and the skin wounds are usually small, hence infeetion is much less likely to occur.

Wounds of joints from the small-bore bullet are therefore less dangerous, and if aseptie seldom lead to any bad result. This was predieted by von Coler as the result of experimental work, and the experience of the campaigns in Cuba, South Africa, and Manehuria has amply justified his opinion. At Harbin, 1,382 penetrating wounds of joints were treated during the year 1904, with 7 deaths, and only 72 resections were performed.[1]

A bullet at high veloeity passing near a joint may cause effusion into it, the joint itself being untouched. This condition is known as **vibration synovitis**, and is eaused by the vibrations set up in the limb by the passage of the bullet through it. It is most marked in fractures of the shafts of the long bones, but may oceur when only soft parts are hit. It is common in the knee with fractures of the femur or the tibia, and in the ankle with fractures of the tibia. In the hip and

[1] Follenfant, *loc. cit.*, p. 90.

shoulder it is not so easy to detect, and in the upper limb it is less marked than in the larger joints of the lower limb. The effusion is serous, and is rapidly re-absorbed. That this condition is not the result of extension of fissures into a joint from a fracture is proved by the fact that there is only serum in the joint, no blood, and that it may be seen without any injury to bone.

A bullet lodged near a joint may interfere mechanically with movement, the joint itself being uninjured. This is a rare condition, and is easily remedied by removing the bullet.

Wounds of joints may be divided into four classes, according as the bones are *uninjured*, *perforated*, *grooved*, or *comminuted*.

(1) **Wounds of joints without injury to bone.**—These are cases in which the capsule of a joint is opened by a bullet that does not touch any of the bones forming the joint. Such injuries are rare, and are seldom seen in any joint except the knee. There is little danger of infection and the wounds usually heal without trouble. The only common sign is effusion of blood into the joint. Discharge of synovial fluid from the wound may occasionally be seen.

(2) **Perforation of the articular ends** of the bones is the most common form of injury to joints by the small-bore bullet. The entrance and exit wounds are small, and nearly equal in size. The bone is usually cleanly pierced without any fissuring or splintering, or at most a splinter is lifted from the surface where the bullet leaves the bone, especially in oblique tracks when the bullet makes its exit towards the shaft, where the surface layer of bone is denser. In other cases there may be some fissuring, as where the track of the bullet is near the surface of the bone, when the roof of the tunnel in the bone may be fissured and broken. High velocity of the bullet tends to cause the perforation to be cleaner. When the bullet strikes perpendicularly to the surface, it traverses the joint by the shortest route and inflicts the least amount of injury. Long oblique tracks through the bones are more serious, as there is greater danger of infection, from the greater length of the track through the bones and the larger size of the oval skin apertures. As a rule clean perforations of joints remain aseptic and do well.

(3) **Superficial grooving of the bones**, though at first sight it may appear less serious

than perforation, is really more dangerous, owing to the greater risk of infection. This is due to the track in the soft parts being rather long and superficial, the entrance and exit wounds often oval and larger than usual, and the wound in the capsule of the joint a superficial rent instead of a pair of small punctures. The edges of the groove in the bone are generally a little splintered. Should any suppuration occur in any part of the track in the soft parts, it can readily find its way into the joint.

(4) **Comminution of the articular ends** is by far the most dangerous variety of joint injury, owing to the difficulty of preventing infection. It is caused by large bullets and by fragments of shell at all ranges; somctimes by the small-bore bullet at short ranges, especially when the shaft is struck close to the articular end, when the comminution may be very great and may extend into the joint. Comminution is more likely to occur in the smaller articular ends, as in the elbow or ankle joints, and where the bone is dense, as in the neck of the femur.

Shrapnel bullcts and fragments of shell cause comminution, with much damagc to the soft parts,

frequently lodge, and often carry in portions of clothing. When the bones are comminuted, the exit wound is often enlarged by fragments being driven out through it. The increased damage to the bones, the greater size of the skin wounds, and the extensive necrosis of soft tissues so commonly caused by any form of shell wound, render the difficulty of preventing infection much greater, and suppuration is much more frequent in injuries of this class. The destructive effects of the larger types of rifle bullet on the articular ends of bones have been already described (p. 109).

Lodgment of bullets in joints is uncommon, except with spent bullets or bullets making irregular impact. It occurs more frequently with the larger types of bullet, or with shrapnel bullets and fragments of shell. With the old spherical musket bullet it was very common.

Symptoms and Course.—The most constant symptom of wound of a joint is hæmarthrosis, the capsule of the joint being distended with blood. This gives rise to a swelling, which is at first tense and elastic, and later, as the serum is absorbed, becomes softer and has a doughy feeling on palpation. The blood is slowly absorbed, and takes from

two to six weeks to disappear, the average duration of the effusion being about a month. There is always some rise of temperature accompanying hæmarthrosis, which is to be explained in the same way as the pyrexia in other extravasations of blood (*vide* p. 77). This is unlikely to cause errors in the diagnosis, as the pyrexia is slight, and is not accompanied by the severe pain and constitutional disturbance seen in acute septic arthritis. In some cases, generally of slight injury to the capsule, there may be no blood in the joint, though some amount of serous effusion is almost invariably present, and in these the diagnosis of wound of the joint is difficult and must depend on the course the bullet has taken.

Escape of synovial fluid from the external wounds is very seldom seen, unless the wounds are of some size and the cavity of the joint communicates freely with the exterior. It is, of course, conclusive evidence that the joint is wounded.

Crepitus is found only when the bone is comminuted or a piece of the articular end split off.

In some cases there may be no symptoms, though the course of the bullet may make it practically certain that a joint has been wounded. In any

doubtful case it is better to treat the injury as one of a joint.

If the wound remains aseptic healing is rapid, and in the majority of the cases perfect movement of the joint is restored. Pain is not severe in these cases, and there is little tendency to the formation of adhesions if the joint is not kept fixed too long. Such simple perforations of joints should give little more trouble than flesh wounds. Where there is much damage to the articular ends movement may be a good deal limited by the formation of adhesions, or by alteration in the shape of the shattered bone causing mechanical interference with movement. Adhesions can be broken down, but deformity of the articular surfaces is less easy to deal with, and if the limitation of movement is very great excision may be needed to restore the function of the limb.

Should the joint become infected, there is at once danger to the limb, and perhaps even to the patient's life, and the ultimate result, if the limb is saved, is in most cases firm fibrous or even bony anchylosis. Acute septic arthritis of a large joint frequently necessitates amputation of the limb, which, however, may fail to save life.

In a few cases quite good movement is retained, even after suppuration, in a joint. Infection occurs more often where the bones are comminuted or grooved, and when the external wounds are large, and almost invariably follows wounds from shrapnel bullets or fragments of shell. It is very uncommon in simple perforations of joints by small-bore bullets, except in the ankle and tarsus.

In rare instances infection may reach a joint by spreading along a fissure from a septic compound fracture, but except in fractures from large bullets such fissures into neighbouring joints are seldom present. Another mode of infection of a wounded joint is more important. If there is a long track in the soft parts a focus of suppuration may form in some part of the track, often very insidiously, and on movement the pus may become diffused along the track and infect the joint, and this, too, when to all appearances the wounds are doing well, as a small deeply seated point of suppuration in the bullet track may cause so little trouble as to escape detection unless very carefully looked for. Two very instructive cases of this accident are recorded by Mr. Makins.[1]

[1] Makins, *loc. cit.*, p. 234, Cases 43 and 44.

In the **treatment** of joint injuries, the first essential is to cleanse and dress the external wounds carefully, so as to prevent septic infection. The limb must be fixed on a splint, with the injured joint in the position that will give the most useful limb should anchylosis occur. As soon as the external wounds have healed, and it is quite certain that there is no concealed suppuration in any part of the bullet track, passive movement should be commenced. It is important not to keep the joint fixed longer than is absolutely necessary, or adhesions will form and give much trouble, and a stiff joint may result. Gentle massage assists the absorption of the blood effused into the joint, and in a few cases where this is very slow to absorb aspiration may be done, the greatest care being taken not to infect the joint, an accident that may easily happen in dealing with a collection of blood-clot, with disastrous results. Aspiration must on no account be attempted until the external wounds have healed, lest foreign and possibly infective matter be sucked from the bullet track into the joint. The final result as regards movement, in uncomplicated joint wounds, depends on the trouble taken during convalescence with passive and after-

wards active movements to prevent adhesions forming.

No kind of exploration or probing of a wound of a joint is permissible, and in aseptic cases any interference is quite inadmissible. Even when there is much comminution of the ends of the bones no operation should be attempted in aseptic cases ; there is nothing to be gained by removing fragments, and there is every danger of infecting the joint. At the worst these injuries will result in anchylosis, which may be remedied by operation at a later date.

If a wounded joint suppurates it must be treated exactly as an ordinary case of acute septic arthritis. Free incisions must be made so as to give the best possible drainage, the joint must be freely irrigated with sterile salt solution or very weak antiseptics, the limb must be kept rigidly fixed, and constant irrigation with drainage kept up until the suppuration subsides. The usual result is anchylosis, rarely more or less movement is retained. In many instances amputation is necessary to save the patient's life; sometimes a secondary excision may save the limb. In case of suppuration of a joint in which the ends of the bones are com-

minuted, all loose fragments of bone must be freely removed; if left they will necrose, delay healing, and keep sinuses open.

Amputation is necessitated by the same indications as in fractures of the shafts: severe damage to the soft parts, rendering the recovery of the limb impossible; gangrene from injury to the main vessels; and such injuries as shell wounds laying a joint widely open, with great laceration of the skin and much smashing of the bones.

Excision is never done now as a formal operation, (with the possible exception of the elbow in certain cases, *vide infra*), but removal of fragments in septic comminuted injuries may amount to an informal excision. Late excisions of anchylosed joints are sometimes required, either to rectify bad position, as in the knee, or to restore movement in the shoulder or elbow.

Wounds of the **shoulder-joint** are not very common. Perforation of the upper end of the humerus often takes place without the joint being implicated. A clean perforation involving the joint gives no trouble, as a rule. The capsule may be injured without damage to the bones by bullets traversing the axilla. Comminution of the head

of the humerus depends on the size and veloeity of the missile, and on the point at whieh the bone is struek. A bullet at high veloeity striking the bone at the anatomieal neek will often produee separation of the head of the bone as one or more fragments ; sinee these are loose in the eavity of the joint, and are eut off from their blood supply, they are very likely to neerose, and will then require removal, the operation amounting to a partial exeision.

When the surgieal neek is struek by a bullet at high veloeity, a great deal of eomminution is produced, and fissures run up and down the bone, splitting up the head and upper part of the shaft, but the fragments of the head remain attached to the periosteum and have a good blood supply, so they will unite, and do not tend to necrose. In sueh eases the fragments need not be removed, unless the joint beeomes septie. Disloeation of the head of the humerus has been known to aeeompany a fraeture into the joint. The most extensive eomminution of the upper end of the humerus does not neeessitate amputation, provided the main vessels and nerves are uninjured ; patients have reeovered with useful limbs after loss of the head of

the humerus and several inches of the shaft. If the forearm and hand can be preserved to the patient they certainly ought to be saved, even at the cost of a prolonged convalescence. Injuries to the head and neck of the scapula are rare, and usually take the form of perforations. The head of the scapula may be extensively broken up, and if the joint is septic removal of the fragments is necessary. In one case in South Africa amputation of the upper limb and scapula was successfully done for a septic wound of the shoulder-joint and scapula.[1] Of the small number of cases reported from South Africa the most noticeable feature was the marked difference as regards sepsis between perforation of the joint and comminution of the bones, 9 perforations all healing aseptically; while of 18 comminuted injuries no less than 16 suppurated, and 5 amputations were done, with one death.[2] Stromeyer's cushion is useful in the treatment of these cases. The danger of gangrene from tight bandaging must not be forgotten.

An occasional accompaniment of injuries about

[1] *Surgical Report, South Africa*, p. 212, Case 72, and Treves, *Med. Chir., Trans.*, vol. 83, p. 282.

[2] Hickson, *Surgical Report, South Africa*, p. 210.

the shoulder is paralysis of the deltoid from injury to the circumflex nerve, when the relaxation of the muscle allows the head of the humerus to fall away from the scapula.[1]

In the **elbow** perforation is not common, owing to the small size and irregular outline of the bones. Wounds of the capsule alone can scarcely occur. The majority of the injuries are accompanied by comminution of the bones, more often of the lower end of the humerus. The upper end of the ulna is more frequently perforated. The result of wounds of the elbow is very often bony anchylosis, movement being retained in a comparatively small proportion of the cases. Owing to the frequency of comminution, sepsis is also common, and operative interference for the removal of fragments is often called for. Removal of fragments in these cases amounts to partial excision, and the result of partial operations on the elbow-joint is unsatisfactory, from the great tendency there is to anchylosis after such operations. Hence the elbow forms an exception to the general rule of avoiding set excision for gunshot wounds. If it is necessary to interfere at all it is better to perform a complete excision

[1] Makins, *loc. cit.*, p. 228.

than to attempt any partial operation. Excision is also frequently required at a later date on account of anchylosis. The results of these excisions of the elbow are good as a rule, if the after treatment is carefully carried out.

In South Africa, of 49 reported cases 13 were perforations, and the remaining 36 comminutions.[1] None of the former suppurated, while at least 25 of the latter were septic, and in 8 cases there is no record as to whether infection occurred or not. Amputation of the arm was done in 7 cases, with 1 death.

In the **wrist and carpus** perforation is the usual form of injury; crushing of the bones is seen only in injuries from large or irregular missiles. Small-bore injuries are almost invariably clean perforations, and generally heal aseptically without trouble. When wounds in this region suppurate, great stiffness of the wrist and fingers generally results, from adhesions in the joints and in the overlying tendon-sheaths.

Amputation is rarely necessary, even in severe injuries from shell fragments or deformed bullets. Removal of necrosed pieces of bone, good drainage,

[1] *Report*, p. 213.

and the continuous arm-bath will generally give fair results. Excision of the wrist for injury is a most unsatisfactory operation, seldom required and hardly ever worth doing, as the result is no better than the condition the operation was intended to relieve. Much may be done in the treatment of these injuries to prevent stiffness of the fingers by careful and persistent passive movements.

Wounds of the **hip-joint** were very fatal injuries under the conditions formerly prevailing. They are still serious, especially when there is comminution of the head or neck of the femur, or of the acetabulum, and the gravity of the cases is much increased if the injury of the joint is complicated by wound of the pelvic viscera, or of the main vessels or nerves of the limb. The hip-joint is comparatively seldom wounded, as in the usual firing position, lying down behind cover, it is one of the least exposed parts of the body.

Perforation of the upper end of the femur, without injury to the pelvis or its contents, is not serious, the joint is not likely to become infected, and there is no break in the continuity of the bone, so a good result is the rule. There may bc considerable difficulty in diagnosis in such cases, as there is no deformity

or crepitus; the direction of the bullet's course is the chief guide. Distension of the capsule of the joint with blood causes a fullness in front, and the femoral vessels are pushed forward just below Poupart's ligament. In doubtful cases X-rays will often clear up the diagnosis. Lodgment of the bullet in the head or neck of the femur is much less common than it was with the older forms of bullet, but sometimes occurs with the small-bore bullet.

Owing to the dense structure of the neck of the femur comminution is fairly often met with from the small-bore bullet, especially at short ranges. The head of the bone may be dislocated, as in a case described and figured by Surgeon-General Stevenson.[1] A skiagram showing a similar condition is at the Royal Army Medical College.

Comminuted injuries are the usual result of wounds from large rifle bullets, shrapnel, or pieces of shell. The diagnosis is seldom doubtful, as there are shortening and eversion of the limb, with crepitus. Infection is very likely to follow, especially if the external wounds are large.

In the treatment of wounds of the hip-joint,

[1] *Wounds in War*, Fig. 64, pp. 233 and 234.

operative interference is to be avoided in aseptic cases. A lodged bullet may require removal at a later date when healing is complete. Perforations do well with rest, and passive movement later. Cases with fracture of the neck of the femur must be treated by weight extension, care being taken to prevent eversion of the limb. Should suppuration occur, the joint must be opened, preferably by a posterior incision or by Kocher's postero-external incision, all loose fragments removed, and free drainage provided. If the head of the bone is much damaged it may be removed as well, thus converting the operation into a partial excision.

After excision of the joint, or removal of fragments from a suppurating joint, extension should be made in the position of slight abduction, so as to bring the upper end of the femur into the acetabulum. Anchylosis will probably follow, and the abduction will cause some tilting of the pelvis, which will compensate for the shortening of the limb.

The treatment of severe and complicated injuries of the hip-joint, where conservative treatment is unlikely to succeed, is most difficult. Primary amputation at the hip-joint for gunshot injury has always been one of the most fatal operations in

surgery, almost every recorded case having died from shock and hæmorrhage. Primary excision is also followed by very high mortality. The objections to any operation on the battle-field apply strongly to these operations, which can hardly be expected to succeed when the patient has to be moved very soon afterwards. If, therefore, the operation can possibly be postponed to the secondary stage, when the chance of recovery is decidedly greater, this should be done, but if the injury is one destroying the limb extensively primary amputation may be unavoidable, as in some very severe shell injuries. In such cases Langenbeck has recommended removing the head of the bone first, leaving the removal of the limb to be done later, so as to lessen shock, and this was successful in one case in which it was tried.[1] Except in the most extensive injuries of the soft parts, an attempt should always be made to save the limb, and if this fails secondary amputation may be done with fair hope of saving life. The statistics of former wars refer to a time when aseptic surgery was unknown, and it may be hoped that better results will be obtained in the future than in the past.

[1] Stevenson, *loc. cit.*, p. 238.

Very few cases of wound of the hip-joint are on record from recent wars. In the Spanish-American war only three cases occurred, with one death. From South Africa seven cases were reported, though probably others occurred, and of these seven two died, both after septic comminuted injuries of the joint and hip-bone. The Russian Red Cross Society's hospital at Port Arthur received six cases of wound of the hip-joint among 1,616 wounded, and of these five were comminuted injuries, of whom four died. These figures are too small to allow of any statistical conclusions being drawn from them.

The **knee** is the most frequently wounded of all the joints. Most of the remarks made above on wounds of joints in general apply without modification to the knee-joint. Simple capsular injuries without damage to bone are not uncommon; the bullet may pass through the supra-patellar pouch, or through the intercondylar notch, or transversely behind the ligamentum patellæ when the joint is flexed. Perforation of the bones is the commonest injury, and the femur is more often perforated than the tibia or the patella. Comminution is seldom seen from the small-bore bullet, but may occur at short ranges. A specimen showing severe com-

minution of the upper end of the tibia by a Mauser bullet at short range is in the museum of the Royal Army Medical College, and is figured by Surgeon-General Stevenson.[1] The results of aseptic perforations are usually very good, though even in these cases anchylosis may exceptionally occur. After suppuration and removal of fragments in comminuted cases anchylosis is the usual result, and it is most important to ensure its taking place in the straight position, otherwise the limb is useless. Exceptionally more or less movement may be retained after suppuration. Secondary amputation may be necessary in some septic cases. Of a series of 95 cases reported from South Africa, 50 were perforations; 55 of the cases required no treatment beyond rest and aseptic dressings.[2] Lodged bullets were removed from 10 cases, removal of fragments was done in 10 cases and a partial excision in one case, incisions for suppuration were required in 7 cases, without further interference, and amputation was performed in 11 cases, with 4 deaths. One case in which the popliteal artery was wounded was treated by

[1] *Loc. cit.*, Fig. 66, p. 242.
[2] Hickson, *loc. cit.*, p. 203.

ligature of the femoral in Hunter's canal, with a satisfactory result.

Wounds of the **ankle** are very unsatisfactory to treat, as they are very often septic, comminution of the bones is often seen, and hence anchylosis or great limitation of movement frequently results. Anchylosis of this joint causes great lameness, and subsequently amputation may be required, as the patient is often better off with a good artificial foot than with an anchylosed ankle. In septic wounds of the ankle-joint amputation is often necessary, and is done with less hesitation when one considers the unsatisfactory result if the foot is saved and anchylosis follows. Excision of the ankle does not give good results, and is not to be recommended for gunshot wounds. Of a series of 40 cases reported from South Africa, more than two-thirds were septic, and 11 amputations were done, with no death.[1] Five of the amputations were for shell wounds, and in three of these cases in which a primary Syme's amputation had been done on the field, re-amputation at a higher level was necessary, a striking illustration of the bad results of primary amputation under field conditions.

[1] Hickson, *loc. cit.*, p. 207.

The **tarsal joints** are usually perforated; comminution is seldom seen except from ricochet or deformed bullets, or from large missiles. As in the ankle, these injuries are very often infected from the boot or sock, and if there is any comminution fragments of bone or of a broken-up bullet often require removal. As in fractures of the metatarsal bones, there is a marked tendency to burrowing of pus in the sole of the foot, and the results are bad, the arch of the foot becomes weak and flattened, and great lameness and pain on walking remain. Here again a good artificial foot is often better than a badly damaged or anchylosed foot. In amputating for these injuries, the best stump is got from a subastragaloid amputation, if the nature of the injury admits of this operation being done.

CHAPTER VII

WOUNDS OF THE HEAD

Gunshot injuries of the head are a common cause of death on the battle-field, and a considerable proportion of the men shot through the cranium die subsequently from the effects of the injury. Those who recover are seldom restored to perfect health and vigour, but suffer in greater or less degree from various physical and mental disabilities, sometimes quite slight, in many cases most distressing and incapacitating. The proportion of wounds of the head to the total number of wounded varies considerably with the nature of the operations. The better protection there is for the troops the larger will be the proportion of head wounds, as the head must of necessity be exposed in taking aim, while the rest of the body remains under cover, hence in siege operations and when much of the fighting is done from temporary or permanent entrenchments more of the wounded will be hit

in the head. The proportion of head wounds to all gunshot injuries was about 20 per cent. in the Crimea, where there was much siege work.[1] The average ratio for all campaigns is about 12 per cent., and this was about the figure in South Africa, where out of 22,461 gunshot wounds there were 2,379 of the head, forming 10·6 per cent. of the total. The mortality in gunshot wounds of the skull in South Africa was 45·5 per cent., but this rate is based on only a small number of the wounds of the head, 211 cases with 96 deaths, a number of the cases not being reported fully enough to be available for statistical purposes.

The entrance wound in the scalp is round or oval, according to the angle at which the bullet strikes, and as the skin is firmly supported by the underlying bone it is unable to give way and stretch before the bullet, so that the size of the skin aperture is rather greater than in other regions. The exit wound is usually very similar to the entrance, and it may be difficult to distinguish between entrance and exit in some cases. Irregular forms of exit are uncommon in the hairy scalp; occasionally in the forehead the exit wound may take the form of a

[1] Stevenson, *loc. cit.*, p. 318.

slit, following the creases of the skin in that region, especially if the velocity of the bullet is low. Large and lacerated exit wounds are seen only at short ranges. Superficial grooving of the scalp is common, and may be accompanied by injury to the cranial vault. In these grooves there is loss of substance of the scalp, with consequent gaping of the wound. The length of the groove depends on the angle at which the bullet strikes, and also on the curvature of the skull at the part struck, long grooves being possible only where the curvature is slight. Where the skull is sharply curved the bullet may injure the bone at the deepest part of the wound, and it is extremely important that in such a case the damage to the cranium, which may be severe, should not be overlooked. Every groove or subcutaneous bullet track in which there is the slightest doubt as to injury to the bone must be carefully examined to exclude the possibility of any such injury.

Injuries of the Cranium.—Contusions of the skull can occur only from missiles with very low velocity, such as fragments of shell, ricochet or spent bullets, otherwise they can hardly be produced by the small-bore bullet. They may be accompanied by symptoms of concussion, and in

some cases by those of laceration of the cortex. Fracture of the outer table alone, without damage to the inner table, is very rare; it may be due to a spent bullet or a fragment of shell, or to a bullet making grazing contact, and is only likely to occur where there is wide separation of the outer and inner tables, as in the mastoid region or over the frontal sinus. A case of this form of injury is recorded by Mr. Makins, and it is noteworthy that in that instance the injury was received at a very long range.[1] Such cases were more common in the days of the old spherical bullet.

Fracture of the inner table alone may occur, and where the outer table is only slightly fissured there may be considerable splintering of the inner table and much laceration of the brain by the fragments, as in a case reported from South Africa, where a bullet glanced off the occipital bone, causing three small fissures, and on trephining twelve fragments of bone were removed from a depth of $1\frac{1}{2}$ inches in the brain.[2]

Depressed fractures of the whole thickness of the skull may be caused by large fragments of shell,

[1] Makins, *loc. cit.*, p. 243, Case 45.

[2] *Report on Surgical Cases*, p. 21, Case 12.

and sometimes by large bullets that have not velocity enough to penetrate the cranium.

All the above injuries are uncommon, and the vast majority of injuries of the cranium from small-bore bullets may be classified as **gutter fractures**, **perforations**, or **penetration** with lodgment of the bullet.

Gutter fractures are produced by bullets that make nearly tangential impact. The bullet itself does not enter the cranial cavity. The scalp may be slit for the whole length of the gutter, but more commonly there are oval entrance and exit wounds. The length of the gutter depends on the curvature of the skull along the line of the bullet's flight, and on whether the bullet takes a very superficial course or passes more deeply. The longest gutters are met with in antero-posterior wounds in the fronto-parietal region. A bullet passing superficially at a low velocity may cause a V-shaped depression of both tables of the skull, the floor of the depression being broken up into several fragments, with more splintering of the inner table than of the outer. More commonly the outer table is cut away, with more or less of the diploe, according to the depth of the track, and

the inner table is fractured and depressed. The deeper the gutter the more of the outer table is cut away and the greater is the comminution of the inner table, which in superficial gutters may be depressed as one long fragment, especially if the velocity of the bullet is low. In deeper gutters and with higher velocity of the bullet the inner table is broken into numerous fragments, which are driven into the dura mater and the brain, and are also displaced sideways beneath the edges of the bone. This lateral displacement is important, as unless it is borne in mind some of these fragments may be overlooked and cause serious trouble afterwards. There is little or no fissuring around the gutter; at the most there may be one or two short fissures an inch or an inch and a half long at the ends.

The dura mater is practically always lacerated, and in the deeper gutters there is a long rent in the dura mater, corresponding to the floor of the gutter. Hæmorrhage is generally slight. Middle meningeal hæmorrhage is uncommon, and does not give rise to compression, as there is free escape for the blood by the wound. The cortex of the brain is lacerated and contused by the fragments of bone driven

into it. The amount of damage depends on the length of the gutter, long antero-posterior gutters often damaging the cortex to a considerable extent in the motor area. High velocity of the bullet also increases the amount of damage to the brain, as the fragments of bone being smaller and more numerous are driven further into the brain.

The mortality of gutter fractures is low. Of a series of 60 cases reported from South Africa 13 died, a death-rate of 21·6 per cent.

Perforating fractures of the skull may be divided into two classes, superficial and deep. The number of these injuries seen in hospitals is about the same as the number of gutter fractures, but it must be remembered that gutter fractures are very rarely immediately fatal, while a considerable proportion of the perforating injuries cause death on the field.

After gutter wounds, superficial perforations come next in degree of severity. The entrance and exit wounds are not very far apart, and the apertures in the skull are oblique. The thin edges of the oblique holes in the skull are broken up and displaced by the wedge action of the bullet, so that the fragments of the outer table are elevated, and

those of the inner table depressed into the brain, especially at the entrance wound, where the propulsive action of the bullet also comes into play, driving the fragments in (*see* diagram, Fig. 14, A).

FIG. 14.—Diagrammatic section of (A) superficial and (B) deep perforating fracture of the skull. The arrows indicate the direction of the bullets' course.

In deep perforations the bullet strikes more perpendicularly to the surface, and takes a deeper course through the brain. In these cases the effect of the velocity of the bullet, that is, the range at which the wound is received, is very marked. At medium and low velocities the entrance and exit wounds in the scalp are of the usual type. In the skull the surface of the bone first struck by the bullet, being well supported by the thickness of the bone, is fairly cleanly pierced, while the opposite

unsupported surface gives way more extensively. Thus the apertures in the skull are somewhat funnel-shaped, with the wider part towards the direction in which the bullet was travelling. The margin of the entrance aperture is formed by the outer table, the inner being broken up and the fragments carried into the brain, whilst the margin of the exit aperture is formed by the inner table, the outer being broken and driven into the scalp (*see* diagram, Fig. 14, B).

In each case it is the unsupported side that gives way, and it is unnecessary to imagine that either table is more brittle than the other. Fissuring around the apertures in the skull is slight ; often there is none ; where fissures exist they are small and the pericranium over them is not torn. At low velocities the displaced portion of bone may be large and single (as in Fig. 16), and may be turned on edge into the brain. More commonly there are numerous small fragments.

The damage done to the brain in these cases depends on the depth and direction of the track, the amount of comminution of the bone on the entrance side, and the velocity of the bullet. At low velocities the injury to the brain is confined to the

FIG. 15.—Aperture of Entry in Frontal Bone.[1] $\frac{1}{2}$ size. (Makins.)

immediate neighbourhood of the bullet track. On the entrance side the fragments of the inner table are driven in, and produce more or less injury, according to the force with which they are projected. Surrounding the bullet track in the substance of the brain are small punctiform hæmorrhages,

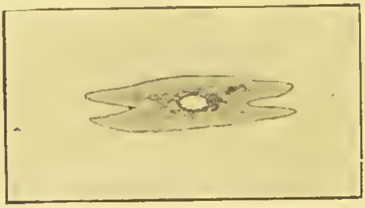


FIG. 16.—Fragment of Inner Table depending vertically upon lower margin of puncture shown in Fig. 15. The centre was perforated. Exact sizo. (Makins.)

[1] Makins, *loc. cit.*, Case 50, p. 252.

caused by rupture of the capillaries from vibrations set up by the passage of the bullet. The brain substance is of course destroyed in the actual track of the bullet. With higher velocity of the bullet the damage is greater, there is more extensive destruction in and around the bullet track, with more numerous small hæmorrhages, comminution

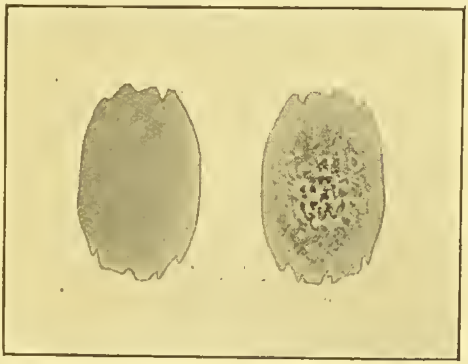


FIG. 17.—Scale of outer table of Frontal Bone and Diploë. Exact size, from fracture in Fig. 18. (Makins.)

is more extensive, and the fragments are driven further in, often to a depth of 1½ to 2 inches in all directions.

At short ranges, 150 yards or less, the damage may be very severe. The entrance wound in the scalp is still small, and there may be no very extensive injury to the bone about the entrance aperture,

or there may be more or less linear fissuring, which is more marked when the entrance is near the base of the skull. The exit wound is large, $\frac{3}{4}$-inch or more in diameter, often lacerated and approaching the "explosive" type. Round the exit wound the bone is extensively smashed into large irregular

FIG. 18.—Perforating Fracture of Frontal Bone from within. Separation of plate outer table.[1] (Low velocity.) $\frac{1}{2}$ size. (Makins.)

fragments, with fissures running towards the base and up into the vertex, and much ecchymosis in the scalp. The dura mater is not only torn by the bullet, there are often separate rents from fragments of bone. In the worst cases at quite close ranges the sutures are torn open, and sometimes large

[1] Makins, *loc. cit.*, Case 54, p. 260.

portions of the skull are blown away. The brain in these cases is extensively pulped and destroyed, and from the exit wound a mass of pulped brain, torn membranes, bone fragments and clot may protrude. There is much hæmorrhage at the base of the brain, and death takes place within a short time of the injury.

The very severe damage at the exit side in these cases is produced by the energy of the bullet, travelling at very high velocity, being communicated to the brain, and through the brain to the opposite side of the skull. Not only are intense vibrations set up—radiating in a cone-like figure from the point of impact of the bullet on the skull to the opposite side, but in these short range injuries the whole brain is violently dashed against the opposite side of the skull, with sufficient force to produce the terrible destruction above described, the brain itself suffering even more severely than the skull.

Bullets deformed by ricochet produce more severe injury to the skull and brain than a normal bullet, as owing to their being deformed they make a larger entrance wound and carry more fragments of bone into the brain.

At extremely long ranges greater damage may

be done by bullets that have lost their regularity of flight and make lateral or irregular impact, or through the bullet rotating or "wobbling" about an axis that does not coincide with its own long axis, when the size of the wound it makes will be increased.

Fractures of the base of the skull are produced by the direct impact of the bullet, and differ widely from the ordinary fractures of the base from indirect violence. Instead of the bone being subjected to stress which causes it to give way along the lines of least resistance, it is smashed directly by the bullet, and so the fracture may be in any region, and does not tend to run through the foramina or the weakest parts of the bone. Hence the common symptoms of bleeding from the nose or ear, or discharge of cerebro-spinal fluid, are not seen unless the cribriform plate of the ethmoid or the roof of the middle ear happens to be directly injured by the bullet. Deafness is, however, not uncommon, and is probably the result of vibratory concussion of the internal ear. The fractures of the base most often seen in hospitals are those of the anterior fossa, damage to the roof of the orbit being met with either as perforations produced by bullets

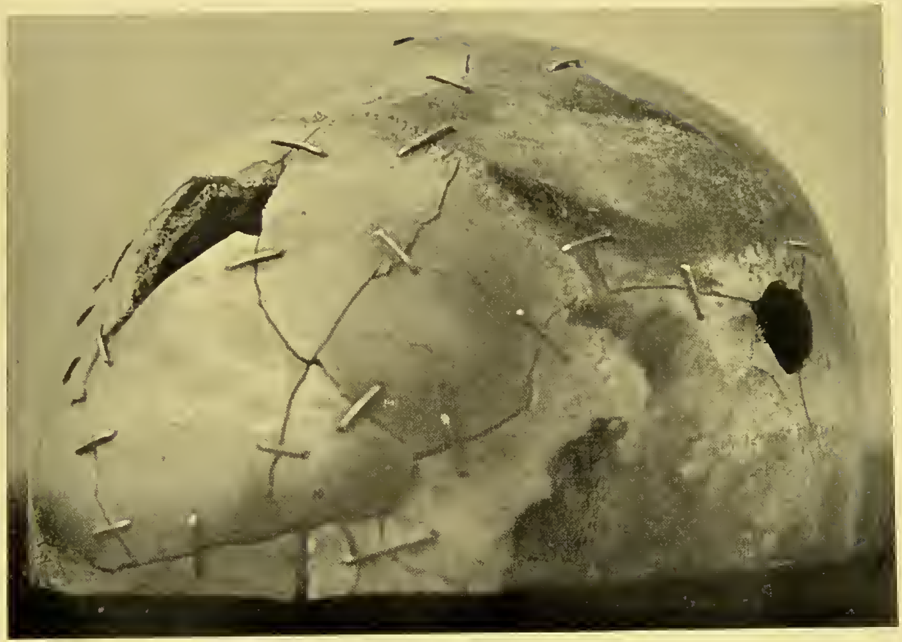


PLATE XII.

Fracture of the skull at a very short range, showing extremely severe injury, more marked about the exit aperture. Entrance in left parietal, exit in right side of Frontal (Stevenson).

[To face page 166.

entering or leaving the cranial cavity through the orbit, or as comminution by a bullet crossing the floor of the anterior fossa. Fractures of the middle and posterior fossæ are more seldom seen, as they are often accompanied by injuries to the base of the brain that prove immediately fatal.

Penetration of the skull with lodgment of the bullet occurs when the bullet has not sufficient energy remaining to enable it to pierce the skull on the far side. This is far more common with shrapnel bullets and fragments of shell, but occurs with the small-bore bullet at long ranges or when deformed by ricochet and much of its energy expended. In these cases there is only one wound in the skull, and this is often irregular in shape, larger than the normal bullet perforation, and accompanied by less comminution of the bone, the fragments being larger and less displaced into the brain. Infection is more likely to occur, and hæmorrhage tends to take place more freely in these injuries, owing to the greater size of the wound. In rare instances the bullet may fracture the skull and rebound, failing to enter the cranium; but this occurs more often with large bullets and with pieces of shell than with the small-bore bullet.

The bullet may lodge in the bone at the point struck,[1] or it may cross the cranial cavity and produce a raised fracture at the opposite side, or may lodge in the bone there.[2] An elevated fracture on the side opposite to the entrance wound may give a clue to the position of the bullet, and enable it to be found and removed, if it has lodged at the point where it was arrested by the bone.[3] In other cases the bullet does not so lodge, but gravitates to the base of the skull.[4] Occasionally the bullet may be localised by X-rays in an accessible situation, and may be removed.[5] Instances of all these possibilities occurred in South Africa.

When there is only one wound in the skull it must not be forgotten that the bullet has not necessarily lodged in the cranium; it may have lodged in, or made its exit from, some other part of the body, the neck or trunk, or it may have entered the skull through the mouth or nose, and the visible wound in the skull may really be the wound of exit.

[1] *Report on Surgical Cases, South Africa*, Case 9. p. 29.
[2] *Report on Surgical Cases, South Africa*, Case 1, p. 28.
[3] Makins, *loc. cit.*, Case 68, p. 284.
[4] *Report, South Africa*, Case 5, p. 28.
[5] *Report, South Africa*, Case 10, p. 30.

Symptoms and course of gunshot wounds of the head.

The damage to the bone can usually be felt through the scalp, especially in gutter fractures. Perforations are easily recognised by the positions of the two wounds. In the more severe injuries at short range there may be the sensation of a "bag of bones" on palpation near the exit wound. External hæmorrhage of any importance is rare, but there is a considerable tendency for blood to accumulate at the base of the brain, especially in the more severe injuries and in injuries near or through the base of the skull. Escape of cerebro-spinal fluid is not very common.

The symptoms of injury to the brain vary very much. In the more serious injuries, such as wounds at short range, or deep tracks involving the base of the brain or traversing the middle or posterior fossa of the base of the skull, the clinical picture is that of intense concussion combined with more or less irritation. There is loss of consciousness, often amounting to deep coma, with flaccid paralysis of the greater part of the body but seldom of the whole of it, accompanied by restlessness and twitchings of the unparalysed parts, sometimes convul-

sions. The pupils in these severe eases are generally moderately eontraeted, seldom unequal or greatly dilated, the pulse slow, in some eases irregular, respiration shallow and often irregular, in many eases more or less noisy but seldom stertorous, sometimes of the Cheyne-Stokes type. The temperature is not mueh raised at first, but may rise to 103° F. or 104° F. in the eourse of a day or two, if the patient live so long. Retention of urine is eommon. These severe eases usually die in from twenty-four to forty-eight hours. In less severe injuries there are sometimes quite slight symptoms, or even none at all. Instanees have been reeorded in whieh bullets have traversed the brain, usually through the frontal region, without giving rise to any symptoms beyond temporary loss of eonseiousness.[1] The dominant feature is usually eoneussion. The extent of paralysis depends on the region injured, and there is often at first extensive temporary paralysis from vibratory eoneussion of the brain substanee suspending its funetions over a wide area around the bullet traek. This is often spoken of as "radiation paralysis," and is

[1] *Report, South Africa*, Case 52, p. 41, and Stevenson, *loc. cit.*, p. 335.

of the same nature as the concussion effects on nerves. It has been supposed by some that radiation paralysis is caused by the minute hæmorrhages into the brain in the neighbourhood of the bullet track, but both the hæmorrhages and the paralysis are probably to be regarded as due to the same cause, the vibrations set up by the passage of the bullet.

Compression of the brain is rarely seen; there is seldom a large enough area of bone depressed to cause symptoms of general compression, and hæmorrhage seldom causes this condition, as the wound acts as a safety valve. Symptoms of compression are more likely to occur when the external wounds are small.

Symptoms of cerebral irritation are very common, and are seen in greater or less degree in the majority of gunshot injuries of the brain. They vary in severity, and include drowsiness, mental irritability, objection to light, contraction or inequality of the pupils, a tendency to lie curled up with all the limbs flexed, muscular twitchings, and in some cases Jacksonian convulsions. Violent delirium and maniacal symptoms are sometimes present. These symptoms, when seen early, are due to irritation of

the brain by clot or fragments of bone ; later they may be due to irritability of those portions of the brain that are recovering from radiation effects, or to localised encephalitis. Loss of function from vibratory concussion or from localised pressure from displaced bone or from blood-clot is generally recovered from, but if due to actual destruction of brain tissue it is permanent.

In fractures of the anterior fossa of the skull there is well-marked orbital hæmorrhage, causing proptosis, increase of intraocular tension, and subconjunctival ecchymosis.

Injuries to the frontal region of the brain are accompanied by very few cerebral symptoms, the chief one being slowness of the pulse.

Where the wound involves the parietal region, especially if the damage is chiefly superficial, all varieties of paralysis from injury to the motor areas of the cortex are seen, including aphasia from lesion of Broca's convolution. Sensory defects in wounds of this region are very rare.

Injuries in the occipital region often cause blindness, which may at first be complete, from the radiation effects, and as these pass off vision is regained to a greater or less extent. In extensive

lesions of both occipital lobes blindness may be permanent, while in partial lesions there is permanent restriction of the field of vision, lateral hemianopsia if one occipital lobe is destroyed, and loss of the upper or lower half of the field in horizontal wounds of both lobes. In some cases there is aphasia from lesion of the visual word centre.

Complications.—Acute diffuse **septic meningitis** is uncommon, although many of the wounds are infected. Even after operations in septic wounds spreading meningitis was very seldom seen in South Africa. In Manchuria the experience of the Russian surgeons was not in accordance with the South African results; at Mukden "the great majority of cases trephined were carried off by diffuse meningo-encephalitis"[1]; this was at the end of the war, and the surgeons were working under great difficulties; infection of the wounds was almost universal, and aseptic work practically impossible. At Harbin the results of operation were much better, probably owing to more satisfactory conditions for surgical work.

Hernia cerebri is common in infected

[1] Follenfant, *loc. cit.*, p. 83.

wounds, and is due either to the development of septic granulations in the wound, or sometimes to the pressure of an underlying cerebral abscess.

Cerebral abscess may occur either early in the case, two or three weeks after the receipt of the injury, from direct infection of some part of the bullet track in the brain, or later, some weeks or months afterwards, when it is usually caused by some foreign body in the brain, commonly a fragment of bone, or occasionally the bullet or a fragment of it. The early form is never seen after primary union of the wound. Late abscesses may be multiple if there are several foreign bodies present. The symptoms of cerebral abscess are vague and the onset insidious. The principal symptoms are headache, drowsiness, slowness of cerebration (often with irritability of temper), mental depression, slow pulse and respiration, subnormal temperature or only slight fever, occasionally one or more rigors. As the intra-cranial pressure increases the pupils become dilated, optic neuritis appears, and cerebral vomiting comes on, with gradually increasing coma. There may be twitchings or convulsions, or localised paralysis, which may indicate the position of the abscess. Usually

the abscess is in or near the bullet track, so that there is seldom much difficulty in finding it.

The **diagnosis** in gunshot wounds of the head seldom offers any difficulties; in most cases the course of the bullet and the nature of the symptoms place the nature of the case beyond doubt. The only cases that are at all obscure are those in which there is a superficial wound of the scalp, and in these the wound must be most carefully examined before the possibility of injury to the skull, with, in all probability, much more serious damage to the brain, can be excluded.

The **prognosis** in gunshot fractures of the skull is always serious, and the mortality high. The severe injuries received at short ranges are very fatal. Speaking generally, the nearer the bullet track is to the base of the brain, the more dangerous is the injury. Wounds in which the bullet has taken a long course deep in the brain are very fatal, and so are direct fractures of the base of the skull, except in the anterior fossa. Hæmorrhage at the base of the brain, or œdema of the brain, often causes death in cases that are not killed by the severity of the initial injury to the vital centres. Of the less severe injuries, perforations

of the frontal lobes are the least serious, and those of the occipital region are also not very dangerous to life. Most superficial perforations and gutters may be expected to do well, if septic complications can be prevented. The usual cause of death, apart from very severe damage to the brain, is sepsis.

In cases that recover, the after-effects are often serious. These include cerebral abscess developing some time after the injury from lodgment of a foreign body in the brain, fits from contraction of the scar and adhesions of the scar or of the dura mater to the brain, and various degrees of permanent paralysis, deafness, blindness and mental defects. The scar is often tender, and slight momentary pressure upon it may cause pain lasting for a considerable time. Headaches are common, and are often very severe and persistent.

It is worthy of note that superficial perforations, though less dangerous than deep ones, are accompanied by more extensive damage to the cortex, and hence often cause greater permanent loss of function when the motor areas of the cortex are involved.

In the **treatment** of these injuries, prevention of infection is of the first importance. The whole of the scalp should be shaved and disinfected. The

usual treatment of any head injury must be carried out, the patient being kept as quiet as possible in a subdued light, the bowels opened by calomel or croton oil, fluid nourishment given in small quantities, and retention relieved by the catheter.

In deciding the question of operation, it must be remembered that the small-bore bullet, if it touches the skull ever so slightly, almost invariably fractures it, and the amount of injury to the inner table cannot be estimated in any case without exploration, but is practically always such as to absolutely demand removal of fragments of bone from the brain, and most serious after effects, such as cerebral abscess, may follow if this is not done. These injuries are of the nature of punctured fractures, and the same rules of treatment apply. Every case, unless recovery is evidently hopeless, must be explored, and this should be done as early as circumstances permit, usually on arrival at a fixed hospital. Where the entrance and exit wounds are near one another they may be included in the same flap, but if they are on opposite sides of the head, as in deep perforations, they will require separate incisions. It is seldom necessary to use a trephine, although this operation is commonly

spoken of as "trephining"; in most cases the already existing aperture in the skull can readily be enlarged by means of gouge forceps. The object of the operation is to remove *all* loose fragments of bone from the cranial cavity, and the openings must be enlarged as much as may be necessary to admit of this being done. Fragments lying in the substance of the brain are best detected by careful and gentle search with the little finger, great care being taken not to damage the brain in searching for them. If the bullet track be explored in this way for a depth of two inches, it is not likely that any fragments will be overlooked. Any sharp edges of bone must be rounded off, and it is important to search for fragments of bone displaced under the edges of the aperture in the cranium. Blood clot should be washed away by gentle irrigation with sterile normal saline, and any softened and disorganised brain substance will be washed away at the same time. Any depressed pieces of bone should be elevated, or if necessary removed. If the wound is aseptic the dura mater should be sutured, to prevent adhesions forming between the brain and the scar; the insertion of thin platinum plates where there has been much loss of bone has

been suggested for this purpose, and may be useful.[1] If the trephine has been used the dise should be replaeed if the wound is aseptie, and any fragments of bone that are of fair size and not too irregular in outline may also be replaeed ; small and uneven fragments are better removed. Any portions of bone it is intended to replaee may be pushed under the scalp at the edge of the operation ineision until they are required, as suggested by Mr. Watson Cheyne. In suppurating wounds the dura mater should not be sutured, and no bone ean be replaeed ; it will eertainly neerose. The operation ineision may be eompletely closed, as the bullet wound provides suffieient drainage.

Both entranee and exit wounds should be explored, as not only is bone often depressed into the brain at the exit wound as well as at the entrance in superfieial perforations, but often it is not possible to say whieh of the two wounds is entranee and whieh exit.

Where hæmorrhage is going on or produeing eompression, any elot, whether intra- or extradural, must be removed, and the bleeding point exposed and seeured by ligature or by under-

[1] Bowlby and Wallace, *A Civilian War Hospital*, p. 229.

running it with a suture, sufficient bone being removed to permit of this being done.

The results of operation are generally good, especially in aseptic cases. Should symptoms of cerebral irritation return after operation this may mean that some fragments of bone have been overlooked, and a second operation may be required for their removal, usually with a satisfactory result. This, at least, is the experience of surgeons in the wars in Cuba and in South Africa. In Manchuria the experience of the Russian surgeons was less favourable as regards early interference in head cases, as has already been stated (p. 173). It is probable that local conditions accounted for their unsatisfactory results, particularly the immense number of wounded they had to deal with, and the fact that aseptic work was admittedly impossible under the circumstances and all wounds were infected. These bad results were obtained in the winter, when the fur cap worn by the Russian troops was a fertile source of infection of head injuries; this may also have contributed to the mortality. In any case, though the patients did badly after operation, it is probable that they would have done still worse without it, not only as regards

the immediate results, but still more as regards later consequences, which must never be left out of consideration in discussing the necessity or otherwise of operation in these injuries.

Hernia cerebri is a rather fatal complication of wounds of the head. It should be treated by removal of its cause, as by drainage of a cerebral abscess when the hernia is due to pressure by it, and by endeavouring to overcome the local septic inflammation when this is the cause. Pressure should not be applied, nor should the swelling be sliced off, as was recommended at one time. Free drainage, cleanliness, and frequent changes of dry dressings are necessary, and a method of treatment that has been found useful is to paint the surface of the protrusion with a 40 per cent. solution of formalin every second or third day.

Cerebral abscesses should be opened and drained as soon as detected. It is generally easy to find the abscess, as it is in or near the bullet track ; but there is often considerable difficulty in maintaining good drainage.

Removal of a bullet lodged in the cranium is possible only in exceptional cases, when it is in an accessible situation and can be accurately localised

by X-rays or other means. Under no circumstances is any prolonged search for a lodged bullet permissible; the search will do far more harm than the bullet would if left alone.

Certain other wounds of the head require brief notice.

Wounds of the mastoid region are almost always accompanied by facial paralysis, due either to concussion of the facial nerve or to hæmorrhage pressing upon the nerve in the aqueduct of Fallopius, or possibly in some cases to direct lesion from a fracture crossing the nerve in its bony canal. The paralysis is often permanent. Another common symptom in wounds of this region is deafness, due most probably to concussion of the internal ear, and also frequently permanent. Sometimes the middle ear is directly injured by the bullet.

Wounds of the orbit are common. Either one or both orbits may be traversed by the bullet, and in wounds of both orbits the sight of both eyes may be destroyed. The walls of the orbit may be cleanly perforated, but are often a good deal comminuted, especially when the bullet travels in the plane of the thin layer of bone. Severe comminution of the roof of the orbit is seen in horizontal wounds crossing

the anterior fossa of the base of the skull. The ocular muscles are sometimes divided. Hæmorrhage is a well-marked symptom in wounds of the orbit, and the wounds are difficult to keep aseptic, possibly from the secretion of the lachrymal gland preventing drying of the wound. Anæsthesia from injury to the branches of the ophthalmic and superior maxillary divisions of the fifth cranial nerve is often seen, and may be temporary if the nerve implicated has been concussed, permanent if it has been divided. Concussion of the optic nerve or of the eyeball causes blindness, which may be recovered from if the concussion is slight, but is often permanent after severe concussion, which in the case of the eye itself sometimes causes multiple small hæmorrhages into the retina. Direct lesion of the eye by the bullet, whether contusion or perforation, causes great destruction and permanent loss of sight; division of the optic nerve also produces permanent blindness, but it may be difficult to distinguish clinically between injuries of the nerve and of the eye itself. The optic nerve is sometimes injured within the cranium, or in the optic foramen.

The prognosis as regards vision is bad unless

early improvement takes place, showing that only slight concussion has occurred.

In the treatment of wounds of the orbit, if the bullet has entered the cranium through the orbit, the entrance wound requires exploration and removal of the fragments driven into the brain. In other cases of fracture of the roof of the orbit it is advisable to wait till the aperture in the roof has closed before removing the eye,[1] should that be necessary, provided that the wound is aseptic. Where there is disorganisation of the eye and the wound is suppurating, no time should be lost in removing the eye and establishing good drainage.

In wounds of the nose the injuries to the nasal cartilages are trifling, being mere slits or small perforations. When the nasal fossæ are traversed there is sometimes loss of the sense of smell from concussion of the olfactory nerves or of the olfactory bulb. Recovery of function is usual in these cases.

The malar bone is generally cleanly perforated, with little or no splintering.

Wounds of the jaws are often met with, and when there is fracture of the alveolar margin the teeth are often broken or carried away, and a

[1] Makins, *loc. cit.*, p. 305.

lacerated wound into the mouth results, which is very difficult to keep clean. In the upper jaw the antrum is often traversed, but these wounds seldom give any trouble. Branches of the superior maxillary division of the fifth nerve may be injured.

Fractures of the lower jaw are common, and are generally much comminuted, but notches and grooves are also seen ; wedge fractures also occur, more often of the alveolar margin. In the treatment of injuries of the jaws thorough and frequent cleansing of the mouth from the first is important when the wounds communicate with the mouth, as they most commonly do. In such cases all loose splinters should be removed, otherwise they will necrose. In fractures of the neck of the lower jaw great stiffness frequently results, so in these cases free removal of loose fragments is advisable to diminish the amount of callus, and movement should be commenced early. Nothing in the way of retentive apparatus is required for fractures of the upper jaw, and for those of the lower jaw the ordinary chin splint and four-tailed bandage give satisfactory results.

Wounds of the soft parts of the face, the cheek, lips and tongue, are of trifling importance and heal quickly, but sometimes cause an unpleasant amount of disfigurement.

CHAPTER VIII

WOUNDS OF THE SPINE

These, when accompanied by serious injury to the spinal cord, are the most hopeless of all gunshot injuries. There are great difficulties in forming a diagnosis of the exact nature and degree of the damage to the spinal cord; very little can be done in the way of active treatment; the difficulties in the nursing and management of the cases are extreme; and, except in the slighter injuries, the results are almost always bad.

The mortality of wounds of the spine in South Africa was 64·5 per cent. (158 cases, 102 deaths), and in Cuba 75 per cent. (36 cases, 27 deaths).

The injuries to the vertebræ by the small-bore bullet are not serious. The bodies are cleanly perforated with no comminution, or at the most a little splintering of the surface layer of denser bone on the exit side, just as in the articular ends of long bones. Larger missiles, leaden rifle bullets of large calibre and shrapnel bullets, break up the

vertebræ and so do much more gross damage to the spinal cord than the small-bore bullet, but the concussion effects of the latter at short ranges more than make up for the slighter damage it does to the bone, as severe concussion destroys the spinal cord as certainly as actual division.

The transverse and spinous processes are not infrequently broken, sometimes without any nerve lesion, in other cases the spinal nerves may be injured as they issue from the spinal canal, and occasionally there may be intra-spinal hæmorrhage. The transverse processes are struck by bullets taking a more or less antero-posterior direction, while those passing transversely or obliquely often strike one or more spines. Longitudinal bullet tracks about the dorsal region are common, owing to the prone position usually assumed under fire, and in these several vertebræ are often hit, the spines being fractured, or if the bullet passes a little more deeply the laminæ may be damaged. The amount of accompanying concussion of the cord in these cases depends on the velocity of the bullet. The cervical spinous processes are seldom injured, being small, deeply placed, and well protected when behind cover.

The damage to the spinal cord is often out of all proportion to the small amount of bone lesion. The injuries of the cord met with are concussion, contusion, partial and complete section, compression by displaced fragments of bone or by hæmorrhage into the spinal canal, and hæmorrhage into the substance of the cord itself.

Concussion of the cord in its uncomplicated form is the result of a bullet striking the spinal column, but not opening up the spinal canal nor causing hæmorrhage or displacement of fragments into it.

It is due to the vibrations set up by the impact of the bullet, just as in concussion of peripheral nerves. As the bone forms an excellent medium for the transmission of vibrations, the severity of the concussion depends very little on the proximity of the bullet track to the cord, but almost entirely on the velocity of the bullet at the moment of striking the spine.

Slight concussion occurs only at the longer ranges, or when the velocity of the bullet has been lowered by a long course through the body before it strikes the spine. The functions of the cord are temporarily suspended, and are regained more or

less rapidly and more or less completely. The symptoms may from the first be only partial, or there may be complete paraplegia below the level of the affected segment of the cord. In some cases recovery commences within a few hours and is complete in a day or two, these are the mildest cases ; while in others paraplegia may last for weeks, and may be accompanied by the formation of bed-sores, and yet improvement may begin and eventually recovery may be practically complete, though in the more severe cases perfect recovery is exceptional. In several instances control of the bladder and rectum was not lost. Cases illustrating all these varieties are recorded by Messrs. Bowlby and Wallace (*A Civilian War Hospital*, pp. 233–5).[1]

In severe concussion, produced by bullets of high velocity at short ranges, the cord is completely disorganised for a length of half an inch or more, and there are often multiple punctiform hæmorrhages into its substance. All the symptoms of complete division of the cord are present, and no recovery of function takes place. In cases dying

[1] *See* also Makins, *loc. cit.*, p. 326, Case 98 ; and *Surgical Report, South Africa*, p. 55, Case 1.

seventeen or eighteen days after being wounded[1] no naked eye changes were seen in the cord, but there was microscopical evidence of degeneration of the nerve-cells of the anterior and posterior cornua. In those that died after six weeks or two months the cord was found converted into a soft yellow substance, compared to custard, at the level of the injury. Evidently severe concussion causes degeneration of the nervous structures of the cord, just as it does in nerve-trunks, with the all-important difference that no regeneration of the damaged elements of the cord can take place.

More or less concussion of the cord accompanies almost every case of spinal injury in which there are any symptoms of cord lesion. The exceptions are uncommon, and include only those cases in which the bullet has so little energy left that it is unable to produce any vibratory concussion. It is practically impossible to distinguish between symptoms due to concussion and those due to direct injury of the cord, and only exceptionally can concussion effects be distinguished from compression by hæmorrhage or displaced bone. Hence the

[1] G. L. Cheatle, *Journal of the Royal Army Medical Corps*, October, 1903.

diagnosis of the nature of the lesion is extremely difficult, and the indications for operative treatment uncertain. In this respect there is a close parallel between these injuries and those of nerves, concussion being the variable and incalculable factor in both classes of injury.

Contusion of the cord is rare, and very closely resembles concussion. It may be due to fracture of a neural arch and momentary depression of the bone by the bullet ; adhesion of the cord to the dura mater at the level of the injury has been supposed to be evidence of this. The effect on the cord is the same as that of concussion, and "custard" degeneration follows. In cases of contusion there must be some concussion as well, and often some hæmorrhage, either intra- or extra-dural.

Division of the cord is seldom complete in wounds by the small-bore bullet, but though the cord may be only partly severed the accompanying concussion destroys the undivided portion and makes the injury equivalent to a total transverse lesion, except when the bullet is so nearly spent that it does not produce any concussion and the damage is limited to the part of the cord actually struck.

Hæmorrhage, both intra-dural and extra-dural,

is not uncommon, but is very seldom sufficient in amount to cause serious pressure on the cord, and is still more rarely enough to produce complete paraplegia. Intra-medullary hæmorrhage is common enough in cases of severe concussion, but the symptoms are then due to the concussion rather than to the hæmorrhage, both of which are produced by the same cause, namely the vibrations set up by the bullet. In one case that died on the eighth day the cord was found full of scattered hæmorrhages for a length of three inches.[1] In cases dying after a long interval the only sign of intra-medullary hæmorrhage is yellow staining of the cord.

Compression of the cord is very rare. It may be due to hæmorrhage, displacement of a fragment of bone, or possibly to a lodged bullet, and it is the only condition in which operation can do any good whatever. There is never any gross displacement of the vertebræ as in fracture-dislocation.

Symptoms and Course.—The signs of injury to the vertebræ are often very indefinite. When the spinous processes are fractured there is usually localised pain and tenderness, often slight irregu-

[1] Makins, *loc. cit.*, p. 322.

larity of the line of spines, and one or more of the spines may be movable, with possibly a little erepitus. In fraetures of the laminæ similar signs are found, often rather more marked. In either ease there is often evidenee of lesion of the eord. Fraeture of a transverse proeess ean only be inferred from the course the bullet has taken or from symptoms of injury to a spinal nerve or to the eord, as the fracture itself gives no direet signs. In perforations of the bodies of the vertebræ there is usually no direct evidence of the bone lesion, and apart from symptoms due to injury of the eord there is often no pain or limitation of movement direetly attributable to the injury of the vertebræ. Angular deformity is very rare, and ean be produeed only by large missiles that break up the bone eonsiderably ; one case of fracture of the spine by a Martini-Henry bullet with well-marked angular deformity is reeorded by Mr. Makins.[1]

Symptoms of injury to the eord may be incomplete or eomplete. Of the partial lesions, slight eoneussion may give ineomplete paraplegia, or the paraplegia may at first be eomplete, but the symptoms begin to improve after a longer or

[1] *Loc. cit.*, p. 318.

shorter interval, as already described. Sensation returns first in these cases, and its return is often accompanied by irritative signs such as pain or hyperæsthesia, due to intra-spinal hæmorrhage accompanying the concussion. Motor power is regained later, and recovery is in many cases not complete for some weeks or months, or may not be complete at all. Hæmorrhage is very rarely uncomplicated by concussion. The diagnosis of spinal hæmorrhage can be made only when the symptoms come on not immediately, but at some little interval after the injury, or when they become aggravated in the same manner. Extra-dural or intra-dural hæmorrhage gives symptoms of irritation of the nerve-roots : pain and hyperæsthesia, usually zonal in their distribution. Intra-medullary hæmorrhage does not give these symptoms. Mr. Makins records a case in which after a wound in the lower dorsal region the symptoms began on the second day and progressed rapidly to complete paraplegia with retention of urine. On the fourth day improvement began, control of the bladder being first regained, and recovery was perfect by the fourteenth day.[1]

[1] *Loc. cit.*, p. 324, Case 96.

Partial symptoms due to localised injury of the cord by a spent bullet, not amounting to complete section and not complicated by much concussion, are very rare.

Symptoms of complete division of the cord are due to severe concussion, to actual section, or to any combination of these two conditions in varying proportion, and in most cases more or less hæmorrhage is also present. Shock is very intense in these cases, more so than in any other bullet wounds. Pain is also generally severe, often agonising, usually zonal and accompanied by hyperæsthesia just above the anæsthetic region, both symptoms being probably due to irritation of the nerve-roots by hæmorrhage. Paraplegia is complete, with flaccidity of the muscles and loss of the deep reflexes. Retention of urine, with overflow from a distended bladder if not relieved, is most commonly present. In some cases there is involuntary and unconscious reflex micturition, and in injury to the lumbar segment the sphincters are paralysed and the urine dribbles away from the empty bladder. Priapism, or rather some degree of turgidity of the penis, is common. There is loss of control over the rectum, with troublesome constipation and meteorism, or in lumbar

lesions incontinence of fæces. Acute sloughing bed-sores come on early, and sometimes quite independently of pressure; in one case in South Africa ulcers developed on the outer sides of both legs.[1] There is great danger of infection of the bladder in these cases, leading to acute septic cystitis and extension of the inflammation to the kidneys causing pyelonephritis. In two cases that survived for some time there was much trouble from the formation of small vesical calculi.[2] Trophic changes in the bladder and kidneys render them much more susceptible to infection.

In cervical injuries the intercostals and most of the accessory muscles of respiration are paralysed, respiration is slow and entirely diaphragmatic, and there may be Cheyne-Stokes respiration. Persistent hiccough is often very troublesome. If the lesion is above the third cervical vertebra the phrenic nerves are paralysed and death occurs at once from cessation of all respiratory movements. The temperature is sometimes high; in other cases it may be sub-normal. The pulse is slow and full. There may be sugar in the urine.

[1] Makins, *loc. cit.*, p. 332, Case 103.
[2] *Report on Surgical Cases, South Africa*, p. 52.

Dorsal injuries are frequently complicated by wound of the lung. There is often irregularity of the heart's action, with irregular respiration and inability to cough, great abdominal distension, and troublesome and persistent vomiting. Lower dorsal and lumbar injuries are often complicated by wound of the abdominal viscera.

All total transverse lesions are fatal sooner or later, generally from lung complications, septic absorption from bed-sores, cystitis and pyelonephritis, ascending myelitis, or spinal meningitis. The infection of the meninges may take place along the bullet track, or from opening up of the spinal canal by a bed-sore.

The **diagnosis** is generally simple enough as far as recognition of the mere fact of injury to the spinal cord is concerned, but the determination of the precise nature and extent of the lesion is very difficult, and in many cases quite impossible. It is seldom that any one of the lesions described above is met with in a pure and uncomplicated form, except concussion; usually concussion, hæmorrhage, and perhaps gross lesion of the cord are all present in varying degrees, and there are seldom clear indications of the nature of the injury. Transitory

symptoms indicate slight concussion. Local compression may be suspected when there is a fracture of one or more of the spinous processes or neural arches, and if in such a case the bullet has lodged, or the wound is known to have been received at a long range, the probability is that the symptoms are not largely due to concussion, as the bullet is not likely to have had sufficient energy remaining to cause marked concussion. A skiagram may assist by showing a lodged bullet or depressed bone. Increase of the symptoms early in the case means hæmorrhage, later it indicates myelitis or meningitis. Functional symptoms sometimes complicate the diagnosis, but they are seen chiefly in the slighter cases, and their irregular character and erratic and often causeless appearance and departure usually make them easy to recognise. A striking case of functional paraplegia after an abdominal contusion is recorded in the *Report on the Surgical Cases in the South African War*.[1]

The **prognosis** has already been indicated. All the cases with severe injury to the cord, amounting to complete transverse lesion, die after a longer or shorter period of suffering, which is often very

[1] *Loc. cit.*, Case 12, p. 70.

severe and distressing, and for which treatment can afford little relief. So painful and hopeless are these cases that patients in whom the cord is severed high up may be considered more fortunate than those with similar lesions lower down, as the former die earlier, and escape much of the misery undergone by the latter, who die just as inevitably, but usually not for several weeks.

The prognosis as regards life is better when the symptoms point to a partial lesion of the cord, and improvement is a hopeful sign. The earlier it commences the better is the prognosis and the greater is the degree of recovery that may be expected. But complete recovery is exceptional in any but the slightest cases of concussion, and as regards after effects a very guarded opinion must be given. In some cases in which paraplegia is at first complete, or nearly so, there may be some remnant of irritability in the muscles, or some trace of the deep reflexes, or control over the sphincters may not be completely lost; and these are indications that the lesion of the cord is not a total one, but is possibly due to concussion from which some amount of recovery may be hoped for, as concussion that has left some part of the cord unparalysed has probably

left other portions capable of recovering their functions.

The **treatment** of these injuries is that of any fracture of the spine with paraplegia, with in addition careful aseptic dressing of the external wounds. Transport is to be avoided, if possible. Absolute rest on a fracture bed is essential, and sometimes the prone position is of use. Morphine must be given for severe pain, but it occasionally fails to give relief. Extreme care must be taken to prevent, or at least postpone as long as possible, septic infection of the bladder, by careful sterilisation of the catheters used and careful cleansing of the meatus, which should be kept covered by an aseptic dressing. Cystitis must be treated by washing out the bladder and by giving urinary antiseptics. The formation of bed-sores is often impossible to prevent, no matter what care and trouble is taken, but everything possible must be done to prevent them, and they must be carefuly cleansed and dressed when they appear. They are one of the most difficult complications to treat under field conditions.

Operation is very seldom indicated, and is still more rarely of any use. It can only be of avail to relieve compression, and then only if the pressure

is the main cause of the symptoms, and the cord has not been destroyed by severe concussion or laceration. Only two recovered out of seven cases operated on for spinal wounds during and after the South African War, and one of these was not a laminectomy, but a case of removal of sequestra from the sacrum and left sacro-iliac joint after a wound of that region, with symptoms of injury to the cauda equina.[1] The other was a wound in the lower dorsal region, causing complete paraplegia at first, but improvement began on the fourteenth day and progressed slowly.[2] The bed-sore that had formed healed, and at the end of three months sensation was almost normal, there was some return of motor power, with spastic symptoms and exaggerated reflexes, and control of the bladder was perfect, though the rectum was still paralysed. Seven months after the injury laminectomy was done by Sir William Bennett, and half a Mauser bullet removed from the cord. Improvement continued, and nearly two years after the injury the patient could walk easily with crutches or a stick, the

[1] *Report on Surgical Cases, South African War*, p. 62, Case 46.

[2] *Ibid.*, Case 42, p. 61.

rectum was normal, and steady improvement was still going on, with a reasonable prospect of nearly complete recovery.

Mr. Makins gives three indications for operation[1]—

(1) Excessive pain above the paralysed region, which being probably due to meningeal hæmorrhage may be relieved by early laminectomy, as in one of his cases,[2] but no further benefit is to be hoped for from the operation.

(2) An incomplete or recovering lesion, with clear evidence of pressure or irritation by displaced bone, and possibly palpable displacement of parts of the vertebra.

(3) Retention of the bullet, with similar signs to those in the last class of case.

Skiagrams should be taken in any case where the symptoms are suspected to be due to pressure by displaced bone or a lodged bullet, before deciding on operation. The earlier laminectomy is done the better, but it may be undertaken at any time up to six weeks after the injury. In one case in South Africa sudden death occurred after laminectomy, apparently as the direct result of alteration in the

[1] *Loc cit.*, p. 340.
[2] *Loc. cit.*, Case 106, p. 335.

intra-cranial pressure from loss of a considerable amount of cerebro-spinal fluid during the operation.[1] Such an accident must be guarded against by keeping the patient prone with the head dependent for some time after opening the spinal dura mater.

[1] Stevenson, *Report on Surgical Cases, South African War*, Case 45, p. 62.

CHAPTER IX

WOUNDS OF THE NECK

UNDER this heading injuries to the cervical region of the spinal column are not included, as they have been dealt with separately.

A considerable proportion of the wounds of the neck prove fatal at once or within a short time, either from hæmorrhage or from injury to the spinal cord. The cases of which there is any record are chiefly those that lived to reach the fixed hospitals; little is known about the cases that died on the field or in the field hospitals, where only brief records, if any, could be kept. Of 604 recorded cases of wound of the neck in South Africa 43 died, a mortality of 7·12 per cent.

Wounds of the neck are often accompanied by wound of other regions—the head, the chest, or the spine.

Most of the wounds seen are transverse or oblique. When the bullet has taken a directly antero-posterior

course, injury to the spinal cord or wound of the large vessels of the neck is common, and as in the latter case the wound in the vessel is near the surface fatal hæmorrhage readily occurs; hence bullet tracks in this direction are not very often seen in hospital. Similarly, when the bullet takes a nearly vertical direction, the wound of the neck may be complicated by fracture of the base of the skull, and these cases also are uncommon. Wounds traversing the neck and chest are more often seen.

Flesh Wounds.—One of the most striking points about bullet wounds of the neck, as seen in hospital, is the frequency with which bullets may traverse the neck in any direction without injuring any important structure. This is the more to be wondered at when one considers how many important vessels and nerves are contained in the neck in a comparatively small space and in close relationship to one another, so that it would seem impossible for a bullet to pass among them without doing serious harm; yet in very numerous instances bullets have pierced the neck in its whole thickness, in every possible direction, with no worse result than a little temporary stiffness, the skin wounds healing under small dry scabs in a few days. In

such cases vessels and nerves that appear to lie directly in the bullet's path in any possible position of the part escape, and the conclusion is inevitable that they must slip or be pushed aside before the bullet, even at the highest velocities. The great elasticity and mobility of the structures in the neck no doubt facilitates this. Several cases of this kind are recorded in the *Report on the Surgical Cases in the South African War.*[1] These surprising escapes seem to be more common when the wound is transverse in direction. The bullet may pass behind the pharynx or œsophagus without injuring either. Even injuries from fragments of shell are sometimes of trifling severity. It must be remembered that only a few of the cases in which important structures are wounded live to reach the fixed hospitals, a fact that accounts for the comparatively large proportion of trivial flesh wounds recorded.

The symptoms of flesh wounds of the neck are not always so unimportant. In a small number of cases a good deal of stiffness of the muscles follows, causing wry-neck or even complete fixation of the head. Suppuration in the bullet track is often the cause of this.

[1] P. 159, Cases 1–5.

Shock is very variable in degree in these injuries; there may be none at all, though the injury is a severe one; or, on the other hand, there may be unconsciousness for several hours. In one case in South Africa in which there was no evident wound of any important structure the patient was unconscious for sixteen hours.[1]

Suppuration in small-bore bullet wounds of the neck is generally due to direct infection from wound of the mouth, pharynx, œsophagus, or air-passages, but wounds of these do not necessarily cause suppuration in the bullet track. Infection may be rapidly spreading and fatal; in other cases it may be limited to the neighbourhood of the wound in the mouth or other septic region. It is quite possible for a bullet to enter by the mouth and yet cause no infection of any part of its track.

Lodgment of bullets or fragments of shell occurs occasionally, but is usually of little importance. The small-bore bullet must be almost spent to lodge in the soft parts of the neck; this circumstance would cause its power of inflicting injury to be very limited, and would enable it to push aside structures more readily. Sometimes fragments of a broken-up

[1] *Report*, Case 6, p. 159.

bullet lodge. There is no difficulty in localising and removing lodged missiles, should this be necessary; in many cases they give no trouble, and may be left alone. The usual indication for removal is some degree of wry-neck, or the presence of the missile preventing a sinus healing.

Wounds of the neck at short ranges show no pronounced increase of severity as compared with wounds at longer ranges, since the resistance of the soft parts is not sufficient to cause much expenditure of energy on the part of the bullet.

Wounds of the larynx and trachea are generally small perforations, and sometimes heal with very few symptoms. In other cases the laryngeal cartilages are a good deal broken up, and in this event tracheotomy may be required for urgent dyspnœa, if the case is seen in time. Hæmoptysis is a common symptom, but is seldom copious. Surgical emphysema is another not uncommon result of these injuries, and may be very extensive, though not of much practical importance. The most serious complication of these wounds is septic broncho-pneumonia, which is very often fatal. In the treatment of these injuries, in addition to the usual cleansing and dressing of the external wound,

tracheotomy may have to be done for the relief of asphyxia, and where there is evident danger of inspiration of septie matter, as when there is a wound of the œsophagus or pharynx in addition to one of the air passages, early traeheotomy may prevent broneho-pneumonia.

Wounds of the pharynx and œsophagus are very fatal injuries, owing to severe deep eellulitis whieh follows in most eases and may prove very rapidly fatal. The œsophagus may be found gangrenous on post-mortem examination. Oeeasionally the only symptom of injury to the œsophagus is some pain or diffieulty in swallowing, and then it is probable that the bullet has grooved the museular eoat of the œsophagus without opening up its lumen, so that the wound eseapes infeetion from the œsophageal mueous membrane. Dysphagia may also appear as a sequel to a wound of the neek when there has been no primary evidenee of injury to the œsophagus, often after suppuration of the wound, and it must then be due to pressure upon the œsophagus or limitation of its movements by the sear. In the treatment of wound of the œsophagus it is not advisable to attempt to suture the wound in its wall. Free drainage is essential, and the external

wound should be enlarged, if necessary, to allow of free escape for the discharge, which is often foul and copious. Nothing should be given by the mouth at first, rectal feeding must be carried out to begin with, and after a few days a stomach tube may be cautiously passed and food administered by it.

Wounds of the large vessels of the neck often prove rapidly fatal. In the cases that live to come under treatment arterio-venous communications are frequently met with. The subject of wounds of vessels and their treatment has been fully dealt with in a previous chapter, and the only point to add is that in dealing with hæmorrhage from a vessel in the neck local ligature at the bleeding point, when practicable, is particularly necessary, owing to the great freedom of anastomosis in this region and the probability of hæmorrhage continuing, often from the distal end, after proximal ligature.

Wounds of large nerves in the neck.—Injuries to the cervical and brachial plexuses and their branches require no addition to what has already been said in the chapter on wounds of nerves. The only branch that needs special mention is the **phrenic,** injury of which may cause some dyspnœa

from paralysis of one-half of the diaphragm, sometimes a sense of constriction round the body (apparently a sensation referred to the attachment of the muscle to the ribs), and in some cases hiccough.[1]

Injury to the **vagus** usually causes only laryngeal symptoms, even when the main trunk of the nerve is injured. There is partial or complete paralysis of one vocal cord, according as the nerve is slightly concussed or completely paralysed, hoarseness or complete aphonia, persistent laryngeal cough, and sometimes vomiting. Acceleration of the pulse is occasionally observed.

Injury to the **spinal accessory** causes paralysis of the trapezius and sterno-mastoid, and injury to the **hypoglossal** paralysis of one-half of the tongue. These are uncommon injuries; in some cases the nerve recovers its function, but when it has been divided recovery seldom follows.

Injury to the **cervical sympathetic** is occasionally seen, and causes suppression of sweating on the side of the injury, contraction of the pupil, and some retraction of the eye-ball, with narrowing of the palpebral fissure, a condition often spoken of

[1] Stevenson, *Wounds in War*, p. 357.

as "ptosis," but better called "pseudo-ptosis" to avoid confusion with genuine ptosis from paralysis of the levator palpebræ superioris.[1] Marked disturbance of the cardiac rhythm is sometimes seen, and occasionally sub-conjunctival hæmorrhage may occur as a result of the vaso-motor paralysis produced by division of this nerve. It can only be in exceptional cases that wound of the cervical sympathetic can occur without injury to the carotid vessels.

In the treatment of these nerve injuries in the neck suture of the injured nerve is very seldom practicable; it is certainly out of the question in division of the vagus or sympathetic, though it may be possible to suture the divided hypoglossal or spinal accessory, or one of the roots of the brachial plexus. The lines of treatment have been discussed in a previous chapter.

The pleura or the apex of the lung may be wounded at the root of the neck, giving rise to symptoms that will be dealt with in the next chapter.

Wound of the thyroid body usually causes no symptoms beyond some hæmorrhage.

[1] Holt, *Report on Surgical Cases, South African War*, p. 167.

Wound of the thoracic duct may occur, though no cases of this accident have been recorded in any recent war. The result would probably be a chylous fistula, with perhaps copious discharge at first. Spontaneous healing may be expected.

CHAPTER X

WOUNDS OF THE CHEST

In dealing with this subject wounds of the spinal column, which have received separate notice, are not included.

Gunshot wounds of the chest may be divided into non-penetrating and penetrating.

Non-penetrating wounds of the chest are of very little importance or interest; a flesh wound of the thoracic wall is no more important than a similar injury in a limb. Long subcutaneous bullet tracks are often seen in this region, and these may be accompanied by fracture of the ribs, sternum, clavicle or scapula.

There may sometimes be great difficulty in determining whether the bullet has penetrated the thoracic cavity or not, especially in wounds about the axilla received with the arm outstretched. It is most important in any doubtful case to reproduce

the position of the patient at the moment he was struck.[1] Hæmoptysis is not certain evidence of penetration, as it is sometimes seen in cases of contusion or non-penetrating wound of the chest wall, and the same may be said of dyspnœa.[2]

Penetrating wounds of the chest were formerly very fatal, owing to the severe injuries produced by the large rifle bullets then in use, and the universal prevalence of sepsis. The small-bore bullet inflicts much less severe injuries, and if the heart and great vessels escape, and septic complications can be avoided, most cases do well. Death on the field is often due to wound of the heart or great vessels. The mortality of these cases in the American Civil War was 62·5 per cent.; in the Crimea it was even higher; while in the Spanish-American War the death-rate in 283 cases was 27·5 per cent.,[3] and in South Africa 482 cases of penetrating wound of the chest gave 79 deaths, 16·4 per cent., while if the 1,223 cases with 149 deaths returned as "wound of the chest" (the fact of penetration not being

[1] See Cases 1 (p. 125), and 54 (p. 145), *Surgical Report, South African War.*

[2] *Surgical Report, South African War*, Case 2, p. 126.

[3] Stevenson, *loc. cit.*, p. 372.

stated) be included, the death-rate falls to 13·4 per cent.

Wounds of the chest are often complicated by wounds of other regions—the arm, neck, spine, and abdomen.

The entrance and exit wounds are generally typical, and it is often impossible to distinguish entrance from exit. Where the bullet strikes obliquely, the oval form of the wound is well marked, and if the skin is supported by a rib or the sternum the wound is slightly larger than in unsupported skin. In the upper intercostal spaces the muscles may be split more extensively than the skin.[1]

The diaphragm may be perforated, often with few symptoms or none directly due to the perforation. If the bullet passes along the surface of the diaphragm it may cut a slit two inches or more in length. The symptoms commonly seen are rapid and shallow respiration, with pain and slight hiccough on inspiration, and sometimes troublesome and painful vomiting.[2]

The ribs and sternum are usually cleanly perforated or notched, or a rib may be completely

[1] Makins, *loc. cit.*, p. 378.
[2] Makins, *loc. cit.*, p. 382.

divided, with some loss of substance and sometimes a little fine comminution. Comminution is more often seen at the head or neck of a rib, or near the angle. The costal cartilages are also cleanly divided or perforated. Both ribs and costal cartilages may be fractured from within by a bullet crossing them on their inner aspect, and either grooving them or producing a fracture with projection outwards of the fractured ends. In such cases several ribs are often injured.

Fractures of the ribs are often attended by none of the ordinary signs; there is no pain or stitch or crepitus. This is owing to there being either a partial division of one or more ribs without complete solution of their continuity, or in the case of complete division of a rib, to there being sufficient loss of substance to prevent the fractured ends touching. With fracture of the ribs from within loss of substance is uncommon, and then there is often a tender angular projection, with crepitus and pain on inspiration.

External hæmorrhage in gunshot wounds of the chest is rare; as a rule there is little or no bleeding from the wounds. Sometimes an intercostal artery is divided, more often at the exit wound by splinters

of rib, and free external hæmorrhage may then occur. Hæmorrhage into the pleural cavity is much more common, and gives rise to hæmothorax.

Infection in gunshot wounds of the chest depends on the same conditions as infection of other bullet wounds. Wounds from the unaltered small-bore bullet are seldom infected; those from bullets deformed by ricochet, large rifle bullets, shrapnel bullets, or fragments of shell or of stone, are usually septic. The pleura is not necessarily infected when the bullet track suppurates, and suppuration may be limited to a small portion of the track. When ricochet or large bullets lodge they frequently cause an abscess at the site of lodgment. Infection of the bullet track or of the pleura may occur from the bullet having passed through the intestine before wounding the chest, and the small-bore bullet may carry infection in this way as well as the larger missiles.

Wounds of the Lung.—The lung is highly elastic and offers very little resistance to the passage of a bullet, hence the track of a bullet through it is small, and sometimes can hardly be traced *post mortem* when death has occurred within a few days. The small-bore bullet causes scarcely more

injury to the lung than would be produced by a moderate sized aspirating needle or trocar. The only dangerous region is the root of the lung, where injury to the large vessels usually causes rapid death. Antero-posterior wounds are less serious than longitudinal ones, in which there is often injury to some of the abdominal viscera as well. The effect of high velocity of the bullet on the lung itself is very slight, the damage being no greater than that caused by bullets at lower velocities, but the effect on the chest wall is of more importance, as with high velocity of the bullet the external wounds are often larger, and there is more comminution of the ribs or sternum, with more extensive injury to the lung by the driving in of fragments of bone.

Symptoms and Complications. — In some cases of gunshot wound of the lung there may be practically no symptoms, even when the bullet has traversed the whole thickness of the chest; in others numerous symptoms, varying greatly in degree and importance, are met with.

Shock varies greatly in degree—in some cases it is extreme, in others it is absent. It appears to depend more on the extent of the injury to the chest wall than on injury to the lung, and often dis-

appears quickly even when severe; as a rule it is slight.

Pain also is sometimes entirely absent; the patient may be quite unaware that he has been hit until he sees blood on his clothes or finds himself spitting blood. It is seldom severe, and is generally transient. It is often referred to some part at a distance from the wound. Pain from injury to the pleura is sometimes severe.

Deficient movement of the chest on the side of the injury is often well marked, and seems to be due to local shock, or in some cases to pain. Mr. Makins notes it as a constant symptom,[1] but it was noted in only a few of the cases reported from South Africa.[2] This discrepancy is probably to be explained by the transitory nature of this symptom, which had disappeared in most instances by the time the patient reached a fixed hospital. Later on fixity of the chest may be due to fluid in the pleura, or to referred pain.

Dyspnœa is present in a considerable number of instances at first, but is seldom marked or distressing. It is sometimes dependent on pain on inspiration,

[1] Makins, *loc. cit.*, p. 387.
[2] *Report*, p. 137.

but is more often mechanical, due to fluid in the pleura. Dyspnœa and pain on exertion are very common after-effects of gunshot wounds of the lung, and may persist for a long time after the wounds have healed. These symptoms are due to pleural adhesions, or to contraction of the cord-like scar of the bullet track through the lung, and often incapacitate the patient for active exertion for a considerable time.

Hæmoptysis is one of the most common symptoms of gunshot wound of the lung, but is not always present. Sometimes it is practically the only symptom. It generally appears early, often immediately after the patient is wounded, and is usually scanty, very seldom in sufficient amount to call for any special treatment. As a rule it lasts three or four days, sometimes longer.

Cough is seldom a troublesome symptom. In a few cases there is a dry hacking cough, which may persist for some weeks.

Cyanosis is occasionally seen, but is then generally slight and soon disappears.

Surgical emphysema of the chest wall occurs in a small proportion of cases, and may be very extensive, but is of little importance. It is more common

with wounds from large missiles and with extensive injury to the chest wall, and generally disappears rapidly.

Pneumothorax is rarely seen. It occurs chiefly after wounds by the larger missiles, or occasionally when the small-bore bullet has wounded one of the larger bronchi or the trachea. Sometimes it is seen in conjunction with pyothorax.

Issue of air from the external wounds is very seldom observed in wounds from the small-bore bullet. It used to be common with the large bullets formerly in use, and may still be met with occasionally in wounds from Martini-Henry bullets and other large projectiles.

Hæmothorax is a common and serious complication of penetrating gunshot wounds of the chest. Probably in nearly every case there is some hæmorrhage into the pleural cavity, but this, if slight, is of little importance and hardly deserves the name of hæmothorax. More copious effusion of blood into the pleura is generally due to hæmorrhage from the chest wall, seldom from the lung itself ; if the blood comes from the lung there is usually persistent hæmoptysis at the same time. As a rule the onset of hæmothorax is gradual, it seldom occurs

immediately on the receipt of the wound, and the effect of transport of the patients in determining its onset is very marked.[1] It is, in the great majority of cases, a recurrent hæmorrhage from the vessels of the thoracic wall into the pleural cavity. Any of the causes that give rise to secondary hæmorrhage in a wound may cause late onset of hæmothorax in wounds of the chest. The symptoms are those of fluid in the pleura, accompanied by some rise of temperature, due to absorption of fibrin ferment; or, according to more modern views, to the presence of staphylococcus albus, which has been proved to occur in blood effusions into the peritoneal cavity. The pyrexia sometimes gives rise to a suspicion that empyema may be present, a point easily settled by aseptic withdrawal of a little of the fluid. Fresh hæmorrhage into the pleura is often indicated by a fresh rise of temperature. The effusion may be large enough to cause displacement of the heart, with rapid pulse, and embarrassment of the respiration. Hæmothorax is very rarely fatal, and the tendency is to spontaneous recovery. The blood usually clots early, but may in some cases remain fluid for a long time.

[1] Makins, *loc. cit.*, p. 389.

The clot is very slowly absorbed, and much of it becomes organised, leading to persistent dulness at the lower part of the affected pleura and the formation of extensive adhesions. Aspiration, unless carried out with strict aseptic care, is liable to cause infection of the blood and convert the case into one of empyema, and the same result is extremely likely to follow incision of the chest in these cases, as it is impossible to remove all the blood, and most difficult to prevent infection of a large amount of blood and clot with an open wound.

Empyema as the direct result of wounds by the small-bore bullet is very rare, unless the bullet has carried infection from some part of the alimentary canal. In wounds from large bullets or fragments of shell empyema frequently occurs early from direct infection of the pleura by the missile, or by clothing or other foreign bodies carried in. In some cases of wound of the chest and liver bile may find its way into the pleural cavity. Infection of the pleura by fæcal matter leads to a very severe and fatal pleural septicæmia.[1] Secondary infection of the pleura as the result of removal of lodged bullets, or of aspiration or incision in cases of hæmothorax,

[1] Makins, *loc. cit.*, p. 437.

is unfortunately common. Severe cases of empyema are often fatal. The signs and symptoms are those familiar to every surgeon, and the general symptoms, pyrexia, wasting, sweating, etc., are very marked in cases following gunshot wounds.

Pleurisy with effusion is occasionally seen as a late complication of gunshot wounds of the lung. Localised pleurisy with friction sounds is common with extensive injury to the pleura, and the friction rub in such cases may persist for a long time, being probably then due to adhesions.

Pneumonia is a rare complication, and when seen is generally to be attributed to exposure rather than to the wound, and is often in the unwounded lung. Around a lodged bullet in the lung a patch of localised consolidation generally forms. Extensive pneumonia is usually fatal. Abscess of the lung is also rare, and when present is usually due to a foreign body carried in, such as a piece of clothing, rarely to a lodged bullet. Gangrene of the lung is another very rare complication; only two cases were reported in South Africa, both of which were fatal.

Lodgment of the bullet occurs not infrequently in the chest wall, very rarely in the lung itself. The large and irregular missiles are much more apt to

lodge than the small-bore bullet. Unless sepsis occurs a lodged missile seldom gives rise to any trouble, but if septic it may cause an abscess in the chest wall or in the lung, or may keep a sinus open.

The **diagnosis** in wounds of the lung is generally easy, the position of the entrance and exit wounds, together with the symptoms, usually rendering the nature of the injury at once recognisable. Most of the complications described above give definite and readily observed symptoms. Hæmothorax is indicated by the physical signs of fluid in the pleura with a moderate degree of pyrexia; while in empyema the constitutional disturbance is much more marked, though the amount of fluid in the pleura may be smaller. The question as to whether blood or pus is present is settled at once in any doubtful case by withdrawal of a little of the fluid with an exploring needle and syringe, with, of course, the most careful precautions to ensure asepsis.

The **prognosis** of uncomplicated wounds of the lung is generally good. Some cases recover completely in a short time. Empyema, pneumonia, and the rarer septic complications, such as abscess or gangrene of the lung, sometimes cause death, and necessarily delay recovery. Hæmothorax often

takes a long time to become absorbed, and some persistent dulness at the basc always follows. The troublesome after-effects of gunshot wounds of the lung, pain and shortness of breath on exertion, lasting for several weeks or sometimes months, have been already referred to.

The **treatment** consists of applying aseptic dressings to the external wounds, with thorough cleansing of the surrounding skin, and ensuring as perfect rest as possible to the patient. The evil effects of early transport in causing hæmothorax have been already mentioned. Hæmoptysis very seldom calls for treatment, if it is severe opium may be given, or inhalations of amyl nitrite. Hæmothorax should not be rashly interfered with; as a rule it is better left alone, but if it is sufficient in amount to cause embarrassment of the heart or respiration the blood must be removed by aspiration, when recovery is gencrally considerably hastened. Aspiration has very often been followed by infection of the haemothorax and its conversion into an cmpyema, though with proper care such an accident ought not to occur. When there is any uncertainty as to the perfection of aseptic methods, as in the movable field units, aspiration is not justifi-

able unless for the relief of really urgent symptoms. Incision of the chest wall for hæmothorax is unnecessary, unjustifiable, and dangerous. It has given good results in a small proportion of the cases in which it has been done; but in many others it has resulted in septic infection and empyema, sometimes with a fatal result, and in any case it can do no more good than will result with much greater safety from aspiration. Empyema, whether resulting from suppuration of a hæmothorax or from direct infection of the pleura, must be treated by thoracotomy and drainage in the usual way as soon as it is recognised.

Lodged bullets ought not to be interfered with, unless they are causing symptoms or are keeping up suppuration in the track. In the case of a bullet lodged in the chest wall in an easily accessible situation the temptation to remove it seems hard to resist, but these are just the cases in which rash removal is likely to result in disaster, and not a few cases of empyema have been caused by removal of superficially lodged bullets in the field hospitals, resulting in infection of the pleura.

Wounds of the Heart and Pericardium.—These are very seldom seen in the hospitals, as

the great majority of such injuries prove immediately fatal, either from hæmorrhage or from stoppage of the heart's action. Of the cases that do not die on the field, the majority die in a few days either from hæmo-pericardium or from septic pericarditis. A few have recovered after symptoms pointing to wound of the pericardium, and sometimes where the course of the bullet has made wound of the pericardium appear certain there have been no symptoms. Cases were seen in South Africa, and others are reported from Manchuria, in which bullets have passed apparently right through the cardiac area, and yet recovery has followed, often with no symptoms.[1] Such cases are hard to explain. On the one hand it has been assumed that wound of the heart by a small bullet, such as the Japanese 6·5 mm. bullet, may be followed by recovery, with, in some instances, no symptoms; and on the other hand these cases have been explained on the assumption that the heart has escaped injury owing to its having been displaced at the moment of receipt of the wound, either from the position of the patient or from the heart having been in systole. It seems difficult to believe, without direct proof, that the

[1] Follenfant, *loc. cit.*, pp. 84, 85.

heart can be wounded and no symptoms ensue, and the following up of some of these miraculous cases to the post-mortem table is the only way in which the question can be solved. Undoubtedly recovery may follow a non-perforating wound of the heart, in rare instances;[1] but in all probability a perforating wound must be fatal, unless immediate operation is possible, which can hardly be the case under the conditions of active service.[2]

The symptoms in wounds of the heart and pericardium are usually intense shock, feeble and irregular cardiac action, faintness and tendency to syncope, dyspnœa, and often severe precordial pain and tenderness. Hæmo-pericardium is indicated by increased precordial dulness, there may be loss of the apex beat, and pericardial friction sound may be present. Suppurative pericarditis causes similar signs, with rise of temperature. Should such a case reach a fixed hospital, it may be possible to open the pericardium and remove blood and perhaps suture a wound of the heart, or in suppurating cases

[1] *Report on Surgical Cases, South African War*, p. 145, Case 57.

[2] A case of successful operation on a perforating gunshot wound of the left ventricle is noted in the *Journal of the Royal Army Medical Corps*, September, 1905, p. 432.

drainage of the pericardium may be attempted, but such cases must always be rare, and the possibility of effective treatment exceptional.

Wounds of other thoracic structures.—Only one case of wound of the œsophagus in its course through the thorax was reported from South Africa, and in that the only sign was dysphagia, the œsophagus probably being bruised without perforation. It is almost impossible for the œsophagus to be wounded in the chest without injury to the spine or the great vessels, which would account for the rarity with which wounds of it are seen. Wound of the great vessels must be fatal very rapidly, while wound of the spine would probably cause an accompanying injury to the œsophagus to be overlooked and not recorded.

As in the neck, the escape of important structures in the chest from injury is often remarkable. The probable explanation is that the loose tissue of the mediastinum allows such structures as vessels to slip aside before the bullet, and so escape injury.

CHAPTER XI

WOUNDS OF THE ABDOMEN

Non-penetrating wounds of the abdomen are not very common, and are of little importance except from the point of diagnosis, as it may be very difficult to exclude the possibility of penetration, more especially since many undoubtedly penetrating wounds cause no symptoms of injury to any of the viscera, so that absence of such symptoms by no means excludes penetration. The positions of the entrance and exit wounds afford the chief guide in deciding whether penetration has occurred or not, the position and attitude of the patient when hit being always taken into account. In some cases the oval form of the skin apertures points to very oblique impact of the bullet, and in others the bullet track may be quite superficial and may be felt under the skin, or be marked by subcutaneous ecchymosis. Bullet tracks in the thicker parts of the abdominal wall and about the pelvis

often give rise to great difficulty in the diagnosis as to whether penetration of the abdominal cavity has or has not occurred, and sometimes this point cannot be definitely decided. Exploratory laparotomy is not justifiable under the conditions that prevail on the field, though occasionally an operation undertaken for other reasons, as for the treatment of a fracture of the pelvis, may clear up the diagnosis. Where the symptoms are negative or very doubtful, exact diagnosis is after all not of very great practical importance, as the treatment of most penetrating gunshot wounds must be expectant, for reasons that will be discussed more fully later, and the diagnosis of penetration does not materially alter the immediate treatment.

Contusion of the abdomen may occasionally be produced by large missiles, such as unexploded shells travelling at very low velocity or making oblique impact (the so-called "wind contusions"), or large fragments of shell or pieces of rock thrown up by shells. The danger here is rupture of some of the abdominal viscera, causing peritonitis or hæmorrhage. One case is on record of a fatal rupture of the small intestine in two places by a spent small-bore bullet that merely abraded the skin of

the abdominal wall without penetrating.[1] In cases of rupture of viscera from contusion of the abdomen it is nearly always the small intestine that is torn, or in some instances the transverse colon; the stomach or bladder may also be ruptured, if full. The rent in the intestine is opposite the mesenteric attachment, usually transverse and of considerable extent, the gut may be completely torn across, and in about 10 per cent. of cases there is more than one rupture.[2] Free escape of the intestinal contents and widespread fouling of the peritoneum is certain to occur. Laceration of the liver or spleen or a tear of the omentum or mesentery causes hæmorrhage into the peritoneal cavity, while rupture of the kidney gives rise to retro-peritoneal hæmorrhage and hæmaturia.

The symptoms in cases of contusion of the abdomen are often very indefinite at first, and by no means necessarily commensurate with the severity of the injury. The early symptoms are more or less shock, with pain, vomiting, rigidity and immobility of the abdominal wall. The intensity of

[1] Watson Cheyne, *British Medical Journal*, 1900, vol. i, p. 1195. *See* also Stevenson, *Wounds in War*, p. 395, and Fig. 117.

[2] Moynihan, *Abdominal Operations*, p. 448.

the shock and of the accompanying symptoms gives no indication of the amount of visceral injury. There may be severe shock from a mere contusion of the abdominal wall; or the symptoms may at first be slight when there is most serious damage to the viscera. The duration of the symptoms is of much more significance than their intensity; if the pulse remains small and becomes more rapid, if vomiting persists, and the abdominal wall becomes increasingly rigid, then rupture of the intestine is almost certain. The "abdominal facies" is also a sign of grave significance. The temperature is often subnormal, and distension of the abdomen soon commences, either from paralysis of the bowel or from free gas in the peritoneal cavity. The liver dulness may be diminished or obscured by either of these conditions. Free fluid in the peritoneum is always a grave sign; the fluid may be blood, intestinal contents, or inflammatory effusion. Vomiting of blood, or passage of blood per rectum, does not necessarily indicate a rupture of the stomach or intestine, either symptom may be due to hæmorrhage from the mucous membrane, without complete rupture. Hæmorrhage into the peritoneal cavity gives rise to the general symptoms of loss of blood; pallor,

a pulse becoming increasingly smaller and more rapid, with a tendency to syncope; at the same time there is often increasing dulness in the flanks. With a large amount of hæmorrhage there may be restlessness, dyspnœa, and great thirst.

The diagnosis in cases of abdominal contusion is often extremely difficult. Early diagnosis is of the greatest importance, as by the time the nature of the injury is clear it is too late for treatment to be of much avail. A close watch must be kept on any doubtful case, and the symptoms carefully observed, especially the pulse rate. Opium should on no account be given.

In treatment absolute rest and starvation are essential at first. Almost all cases in which there is rupture of any of the hollow viscera die from general peritonitis unless operated on in time, and intra-peritoneal hæmorrhage from rupture of the liver or spleen or the vessels of the omentum or mesentery is also almost certain to prove fatal. Therefore, as soon as there is sufficient evidence to justify a strong suspicion of damage to any of the viscera, the abdomen must be opened and arrest of hæmorrhage and suture or resection of the damaged bowel performed. Such cases are not promising,

especially under the conditions attending operation in the field, but they are certain to die if not operated on, and must therefore be given the chance of recovery that operation affords. The prospect of saving life is not very good even under peace conditions, the mortality of 376 published cases being 51·6 per cent.,[1] a figure that probably does not represent the true mortality, as successful cases are more likely to be published than unsuccessful. In the field the prospect of success is still more slender, and there is naturally more hesitation in operating than would be felt in a well-equipped hospital, laparotomy being so much more serious and dangerous under field conditions. Fortunately cases of this kind are rare.

As regards the nature of the visceral lesions, the prognosis without operation, and the treatment required, these cases of contusion with rupture of viscera differ very markedly from those of perforation of the abdomen by bullets.

Penetrating gunshot wounds of the abdomen are, and always have been, very fatal injuries. In the Crimea and American Civil War the mortality was 90 per cent., in the Spanish-

[1] Moynihan, *loc. cit.*, p. 453.

American War it was 72 per cent.,[1] and in South Africa there were 1,304 cases with 588 deaths, a mortality of 44·7 per cent. The improvement in the results of these injuries has been due to the less dangerous nature of the wounds from the modern bullet rather than to advances in surgical treatment, for modern methods of abdominal surgery have proved inapplicable to gunshot wounds in the field, as will be shown presently.

The injury done to the wall of the intestine by the small-bore bullet depends on whether the bullet strikes the gut centrally or grazes it laterally. Lateral contact of the bullet may produce a localised contusion of the intestinal wall, with sub-peritoneal ecchymosis, but no actual damage to any of the coats. The next degree of injury is grooving of the wall of the intestine, with division of the peritoneum or of both the peritoneum and the muscular coat. In some of these grooves the mucous membrane may be perforated at the centre of the groove, the aperture being small and rounded in grooves across the long axis of the gut, while in longitudinal grooves a long slit may be cut through the whole thickness of the intestinal wall. These long slits

[1] Stevenson, *loc. cit.*, p. 419.

are more often seen in the fixed portions of the intestine. When the intestine is struck at right angles to its surface, the bullet makes a small clean round perforation on the entrance side, and either a similar round hole or a somewhat valvular curved slit on

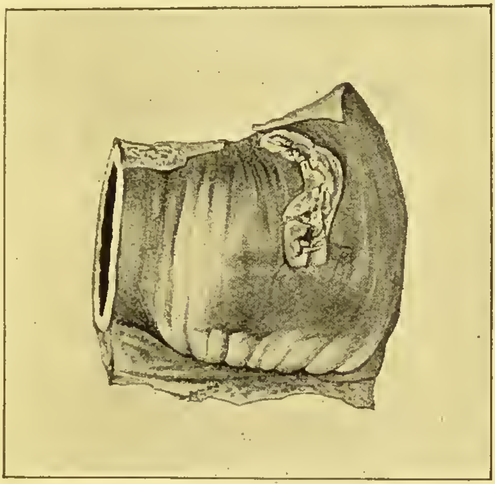


FIG. 19.—Gutter Wound of Small Intestine caused by lateral impact. Position of shallow portion of gutter indicated by deposition of inflammatory lymph. Circular perforation (St. Thomas' Hospital Museum). (Makins.)

the exit side. There is a good deal of ecchymosis of the intestinal wall round all these various injuries, and this is visible beneath the peritoneum and also under the mucous membrane if the gut is laid open. The wounds may be in any part of the intestine, and the nearer they are to the attach-

ment of the mesentery the greater is the probability of bleeding from the vessels in the wall of the in-

FIG. 20.—Perforating Wounds of Small Intestine.

A. Entry; uote circular outliue and eversion of mucous membraue. B. Wound of exit; curved slit-like character, eversion of mucous membrane. Note the localised ecchymosis, more abundaut round exit aperture. (St. Thomas's Hospital Museum.) (Makins.)

testine, a point of some importanee, as such bleeding tends to diffuse infeetion more widely through

the peritoneal cavity. As in all punctures of the intestine, the mucous membrane tends to prolapse and block the openings in the wall of the gut.

Wounds of the large intestine are exactly like those of the small intestine, and wounds of the stomach are very similar. Long slits in the wall of the stomach are sometimes cut by the bullet, especially about the lesser curvature. The bladder also may be either perforated, or slit by tangential impact of the bullet. Perforation of the omentum or mesentery is often attended by dangerous hæmorrhage from division of some of the numerous vessels of these structures. Larger missiles produce injuries very similar in type to those produced by the small-bore bullet, but of larger size, and the small intestine may be more or less completely divided by such a missile as the Martini-Henry bullet. Prolapse of omentum or of intestine through the external wounds made by the small-bore bullet is practically impossible, but is sometimes seen from wounds by large rifle bullets or shrapnel bullets.

The solid organs, liver, spleen, and kidney, are usually perforated or superficially grooved by the small-bore bullet, the track being of small size,

16

without any laceration. Larger missiles cut a larger track, and often produce a considerable amount of laceration of these organs. At quite short ranges the small-bore bullet may produce very extensive laceration of the liver and spleen and kidneys, resembling the hydro-dynamic effects seen in the brain.[1] In the stomach and bladder also "explosive" effects are produced; if these organs are struck at short range when full they are burst and lacerated extensively. These injuries were not observed in South Africa, though possibly they may have occurred there, but were seen in Manchuria by the Russian surgeons as the effect of the Japanese 6·5 mm. bullet. They must always prove quickly fatal, and so are little likely to come under surgical observation.

In penetrating gunshot wounds of the abdomen injury to one organ only is exceptional. Multiple injury is the rule; there may be numerous perforations in the intestine, as well as damage to other organs, the omentum, mesentery, liver, spleen and kidney. Wound of the chest by the same bullet is very common, occurring in at least 30 per

[1] Hoff, *Journal of the Association of Military Surgeons*, August, 1906.

cent. of abdominal wounds;[1] also wounds of the hip and thigh are common.

The small-bore bullet does not produce "explosive" wounds in the abdominal walls, except in a small proportion of cases in which bone is struck, and large external wounds are mostly due to large missiles, or to bullets deformed by ricochet or striking irregularly at very long ranges.

Symptoms and Course.—As in the case of rupture of the intestine or other abdominal organs from contusion, so also in penetrating gunshot wounds, the symptoms directly due to injury to the hollow viscera are exceedingly vague and indefinite. Pain and shock vary greatly in different cases, and give no clue to the amount of internal damage that may be present. Vomiting may be slight or absent at first. Immobility of the abdominal wall is often localised at first to the neighbourhood of the external wounds, and is due to local shock. There is usually some local tenderness, due more to the wound of the parietes than to injury to the underlying viscera. It may, in fact, be said that injury to the abdominal viscera gives rise to no direct and constant local symptoms by

[1] Makins, *loc. cit.*, p. 471.

which the nature of the lesion can be recognised, and that the accompanying general symptoms, such as shock and vomiting, are at first too variable and uncertain to be of any value in determining the severity of the case. The diagnosis must therefore depend on the occurrence of either hæmorrhage or peritonitis. Of intra-peritoneal hæmorrhage sufficient has been said when discussing contusions of the abdomen; it is a condition generally easy to recognise from the local and general symptoms familiar to every surgeon. The signs of commencing general peritonitis have also been detailed under the same head, and need not be repeated here. They give the only definite indication of a perforating wound of the intestine, with certain rare exceptions, which will be given later.

Peritonitis, however, is by no means the inevitable result of a penetrating gunshot wound of the abdomen. One of the most striking features of these cases, as seen in South Africa and in other recent wars, and one that certainly was not anticipated from the experience of former wars, was that a considerable proportion of the cases recovered without operation, and many of them with only slight symptoms.

Of 207 cases of penetrating gunshot wounds of the abdomen reported in some detail from South Africa,[1] 63 died (30·4 per cent.) and 144 recovered. 8 of these recoveries followed laparotomy, and 28 followed operations for localised abscesses. The remaining 108 recovered without any operation. Of these 108 cases 83 had such ill-defined symptoms that the diagnosis of injury to any particular viscus could not be made, and half of them had no symptoms of any visceral injury at all. It must be pointed out that these figures do not represent the true mortality from this class of injury, which was nearly 45 per cent., owing no doubt to cases that recovered being more often recorded in detail than those that died. The great majority of cases in which injury to the small intestine could be diagnosed with any certainty died. This is equivalent to saying that such a diagnosis can, as a rule, be made only when symptoms of general peritonitis set in. The absence of such symptoms must mean that infection of the peritoneum sufficient to cause general peritonitis has not taken place. As to the explanation of this, there is some difference of opinion among surgeons who had much experience in South Africa,

[1] *Report on Surgical Cases, South African War*, p. 120.

and unfortunately any conclusions drawn have to be based largely on general impressions and more or less theoretical grounds, as the evidence available is scanty. Most of the recoveries took place without operation, and in but few of the fatal cases was a careful post-mortem examination possible, so little direct information from operations or post-mortem examinations is forthcoming.

Two explanations have been put forward—(1) That a bullet may pass through the abdomen and among the coils of the intestine without any perforation of the intestine being produced; and (2) that the intestine may be perforated without causing sufficient infection to set up general peritonitis. The question as to which of these explanations is the true one in the majority of cases is not one of purely academical interest, as if the intestine really escapes perforation it is clear that the treatment of these cases as regards feeding and movement may be considerably modified without risk.

The view that the intestine frequently escapes perforation by a bullet passing among its coils is upheld by Mr. Makins.[1] He lays stress on the escape

[1] *Loc. cit.*, p. 411.

of other structures, such as nerves, through displacement; and points out that the small intestine is exceptionally well arranged to escape injury, owing to its mobility, lightness, elasticity and compressibility, and to its being so arranged that in certain directions a bullet may pass almost parallel to the long axis of its coils. A case frequently quoted in support of this view is one recorded by Mr. Lenthal Cheatle.[1] A Mauser bullet entered just above and a little in front of the highest point of the iliac crest on the right side, and was found impacted in the exit wound, base foremost, at a corresponding point on the left side. Death from general peritonitis followed in forty-eight hours. At the post-mortem two small apertures were found in the cæcum, but no extravasation or peritonitis on that side. In the sigmoid flexure there were two large lacerations, which had allowed free extravasation of the contents of the bowel, giving rise to the fatal peritonitis. There was no sign of any injury to the small intestine lying between these two situations, though careful search was made. This case has been generally held to prove the possibility of escape of the intes-

[1] Cheatle, *Journal of R.A.M.C.*, January, 1905; and *South African Report*, Case 74, p. 90.

tines from injury by a bullet passing among them. There is, however, some doubt as to whether the bullet did actually pass among the coils of small intestine in this case, as careful examination on the cadaver has shown that with the entrance and exit wounds in the positions described the course of the bullet between the cæcum and the sigmoid flexure would probably be almost entirely extra-peritoneal, through the body of one of the lower umbar vertebræ, not among the coils of small intestine.[1] If this were so, it would account for the large size of the wounds in the sigmoid flexure, which was probably due to the bullet turning over on a transverse axis. The loss of velocity from striking the vertebra would be likely to cause this irregular rotation, and the position of the bullet base foremost in the exit wound supports the belief that such a rotation occurred. It is difficult to understand on any other hypothesis the large size of the wounds in the sigmoid, with the total escape of the small intestine from even contusion or abrasion. The fact that no extravasation took place from the wounds in the cæcum tends rather to support

[1] Stevenson, *Journal of R.A.M.C.*, January, 1905; and *South African Report*, p. 74.

the belief that perforation of the intestine may occur without any extensive soiling of the peritoneum.

Other cases are on record in which the escape of the intestines cannot be doubted. Dr. Robinson reports a case[1] from the Philippines in which a ricochet small-bore bullet entered two inches above the border of the ribs in the left mammary line, and passing downwards and backwards lodged in the left loin. On opening the abdomen it was found that the bullet had passed through the omentum and mesentery, but that the intestines had entirely escaped injury. The bleeding arteries were tied, and the patient recovered. In another case reported by Mr. Makins[2] the abdomen was opened on the fourth day for hæmorrhage; no sign of peritonitis was found, and no perforation of the stomach or intestine, but "on two coils of jejunum there were deep slits ¾-inch long, extending through both peritoneal and muscular coats." On other coils "oval patches of ecchymosis, due to direct bruising, were present." No bleeding point was discovered. The patient died next day in collapse, apparently

[1] *Annals of Surgery*, February, 1901, p. 134.
[2] *Loc. cit.*, p. 432, Case 169.

due to fresh hæmorrhage, and no post-mortem examination was made.

The other explanation, that when the intestine is perforated by a bullet extravasation does not necessarily occur in sufficient amount to set up general peritonitis, rests on the following considerations.

The wound in the intestinal wall is a small perforation, one-third of an inch or less in diameter. Prolapse of the mucous membrane into this small aperture occurs at once, and temporarily prevents escape of the intestinal contents. Local shock from the injury probably causes cessation of peristalsis in the wounded coil, as well as cessation of respiratory movements of the abdominal wall. Thus the wound is temporarily plugged, and the damaged coil is placed in a most favourable condition for forming adhesions to neighbouring coils. The temporary blocking of the perforations may be overcome, and extravasation produced, by either distension of the intestine or manipulation by the surgeon.[1] The fact that the intestine is frequently empty at the time of being wounded has been supposed to aid in preventing escape of contents, but

[1] Moynihan, *Abdominal Operations*, p. 99.

though in the case of the stomach its being empty is of considerable importance, it is doubtful whether the small intestine is ever quite empty. Another supposition is that escape of gas from the wounded coil allows it to collapse, but this would be more likely to spread infective material than to limit its escape. It has also been imagined that spasm of the muscular fibres of the wall of the intestine may exert a sphincter-like action and help to close the wound, but this is a mere hypothesis, and is scarcely consistent with the strong probability that injury to the intestine causes cessation of muscular movement in the affected coil.

Next to the immediate temporary blocking of the apertures in the intestinal wall, the most important factor is the rapid formation of adhesions to neighbouring coils and to the omentum, definitely sealing the apertures. Direct evidence of this has been found at operations and at post-mortem examinations; even in cases that died of general peritonitis the coils were sometimes found adherent, though sufficient infection to set up peritonitis must have taken place before the adhesions could form. In other cases the apertures were found blocked by prolapse of the mucous membrane, and

no escape of the contents of the intestine took place until the gut was freely manipulated. Sir W. MacCormack describes a case[1] in which on opening the abdomen eight hours after the receipt of the wound, "the greatest difficulty was experienced in finding the intestinal wound. There was no sign of extravasation, and the seat of injury was only discovered after much handling and squeezing of the bowel." Sir F. Treves says[2]—"I am certain that the hole is closed almost directly by the apposition of adjacent coils of intestine." He also says—"I found in one or two abdominal sections I made that I did nothing but harm, because in searching for the damage I opened wounds which were already closed."

The bad effect of early transport was particularly noticeable in South Africa, and it was noted that of the abdominal cases that recovered and returned to England the majority had been left on the field for some hours before being moved.[3] If recovery depends on the intestines having escaped perforation, early movement of the patients ought not

[1] *Med. Chir. Trans.*, vol. lxxxiii, p. 317.
[2] *Ibid.*, p. 290.
[3] Dick, *Med. Chir., Trans.* vol. lxxxiii, p. 333.

to have any adverse effect on their chance of recovery.

In the absence of more decisive evidence it is impossible to come to a definite conclusion as to which of these explanations accounts for the majority of the cases that recover spontaneously. It must be admitted that it is possible for a bullet to pass through the abdominal cavity and not cause any perforating lesion of the intestine, but taking all the facts into consideration it seems probable that the majority of the cases of penetrating gunshot wound of the abdomen that recover have the intestine perforated, and that the perforations, when small and not too numerous, become sealed in the manner above described, so that sufficient infection to cause general peritonitis does not take place.

In this connection it must be remembered that the peritoneum is capable of dealing with a considerable amount of infective material, and that the production of general peritonitis depends largely on the quantity and virulence of the organisms with which the peritoneum is infected.

When escape of the intestinal contents does take place from the wounded gut, the amount extravasated is seldom large, except when the lesion in the

intestinal wall is of some size, as in injuries from large or deformed missiles, or when the small-bore bullet cuts long slits through the whole thickness of the wall of the gut.

Internal hæmorrhage was noted in 25 out of 207 cases in South Africa, with 17 deaths.[1] Probably hæmorrhage was the cause of death in many of the wounded that did not live to reach hospital. Wound of the great vessels in the abdomen, or of their larger branches, must be rapidly fatal.

Formation of a localised intra-peritoneal abscess is not uncommon in wounds of the large intestine, the spread of infection being limited by adhesions. This is very seldom seen in wounds of the small intestine.

Wounds of the portions of the large intestine not covered by peritoneum are far more dangerous than wounds of its peritoneal surface. In an injury of this nature there is no tendency to the formation of adhesions that will shut off the interior of the bowel, and the least amount of fæcal infection of the retro-peritoneal tissues is sufficient to set up severe cellulitis, from which most of these cases die. Of 13 deaths in 47 cases of wound of the large

[1] *Report*, p. 74.

intestine reported from South Africa, fæcal cellulitis was the cause of death in 11, and internal hæmorrhage in the remaining 2. All the cases of extra-peritoneal wound of the colon seen by Mr. Makins in South Africa died.[1] In two cases recorded by Mr. Makins death was due to escape of fæces into the pleural cavity from wound of the colon, giving rise to septicæmia from absorption by the pleura.[2]

Although in the great majority of instances in which the intestine is wounded the only symptoms on which a diagnosis can be based are those of the commencement of general peritonitis, there are a few signs that make it certain that the intestine has been wounded. These are all rare, and are seldom of any practical use in the diagnosis. They may be briefly mentioned.

Escape of intestinal gases from the external wounds is rare, and if it does occur it usually does so very shortly after the receipt of the wound, often before the patient comes under observation. Emphysema of the abdominal wall round the wounds is very rare.

The appearance of fæcal matter in the external

[1] Makins, *loc. cit.*, p. 419.

[2] *Loc. cit.*, p. 440, Cases 182, 183.

wound is a certain proof that the intestine has been perforated, and the nature of the matter may indicate the portion of the gut injured. This sign is very seldom seen in wounds from small-bore bullets ; it may occur in extensive injuries of the abdominal wall by large missiles. It is often late in appearing, perhaps only twenty-four to forty-eight hours after the receipt of the wound.

Protrusion of a wounded loop of intestine from the external wound can only occur when the latter is of some size. It is extremely rare, but may be seen in wounds from large missiles. One case was seen in South Africa, in a wound from a Martini-Henry bullet.[1]

As a surgical curiosity escape of intestinal parasites from the external wounds must be mentioned, as it has been known to occur. In one case in South Africa segments of tapeworm were discharged through a fæcal fistula.[2]

In rare cases the bullet has lodged in the intestine and has been passed from the anus. This is only likely to happen with such a missile as the old spherical musket ball, or possibly a shrapnel bullet.

[1] *Report*, p. 83, Case 28.
[2] *Report*, p. 87, Case 51.

Inflation of the bowel with hydrogen has been tried in America as a test in cases of suspected perforation of the intestine. It is a method altogether unsuitable for use in the field.

The **diagnosis** of wound of the intestine, in the vast majority of cases, cannot be made until symptoms of commencing general peritonitis or of a localised intra-peritoneal abscess make their appearance. These symptoms have already been discussed when speaking of contusion of the abdomen. Exploratory laparotomy in doubtful cases is hardly ever justifiable in the field, though it would be done without hesitation in the same class of case under ordinary circumstances. In a penetrating gunshot wound of the abdomen the course of the bullet often affords some indication of the part of the intestine or other organ that has probably been struck. Thus antero-posterior wounds near the umbilicus indicate probable injury to the small intestine; in the flanks, the ascending or descending colon; below the costal margin, the stomach or transverse colon. When the wound is transverse, oblique, or vertical several different portions of the alimentary canal may be injured, as well as the solid viscera, and in many cases the thoracic organs also.

The **prognosis** depends on the diagnosis, and is therefore equally uncertain in any given case. The prognosis of penetrating abdominal wounds in general is unfavourable. The most fatal of all are wounds of the small intestine, next to these come wounds of the transverse colon, which is very similar to the small intestine in its anatomical relations, being attached by a mesentery and freely movable; next in severity come wounds of the descending colon, rectum, and sigmoid flexure, and the prognosis is best in the cæcum and ascending colon.

The course of the bullet also affords some guidance in prognosis. Transverse wounds from flank to flank through the small intestine area are very dangerous, and so are antero-posterior wounds near the umbilicus, from the great probability of multiple wounds of the small intestine. Oblique wounds from the anterior abdominal wall to the flank, or from the flank to the loin, are less dangerous, as the large intestine is more likely to be hit. Antero-posterior wounds outside the small intestine area are also less dangerous, the organs liable to injury being the stomach, large intestine, or bladder. Vertical wounds are dangerous on account of the probably extensive nature of the injuries and their

complication by wound of the chest. The greater danger of extra-peritoneal wounds of the large intestine has already been alluded to.

The important practical point in diagnosis and prognosis is to distinguish, if possible, between the cases that are likely to recover spontaneously and those that will go on to general peritonitis. Considered from this standpoint all penetrating wounds of the abdomen (excluding extra-peritoneal wound of the large intestine) fall into three main classes.[1]

(1) Cases that die early, either on the field or shortly after reaching the field ambulance, from shock and hæmorrhage. These are the most severe injuries, and include most of the wounds from large missiles. Most of them are hopeless from the first; they may be looked on as mortally wounded, and are beyond surgical aid, except in a very few instances where arrest of hæmorrhage may possibly save life.

(2) Cases in which the injury is not immediately fatal, but general peritonitis follows, and death results in from three days to a week.

(3) Cases that do not develop general peritonitis,

[1] Makins, *loc. cit.*, p. 427.

and recover spontaneously, often with very slight symptoms.

The distinction between these last two classes of case, in the early stage, is usually impossible. If exploratory laparotomy were justifiable it would be the only means of settling the question, but unfortunately experience has abundantly proved that laparotomy in the field is more dangerous than the gunshot wound for which it is performed, and in most cases the onset of peritonitis, or its failure to appear, is the only thing that settles what the fate of the patient will be. Many surgeons of great experience, who saw large numbers of gunshot wounds of the abdomen in South Africa, admitted that no amount of experience of these cases enabled them to form any opinion as to the course that a perforating gunshot wound of the abdomen would follow.

Treatment of Penetrating Gunshot Wounds of the Abdomen.—The general treatments is that of any severe abdominal injury. Absolute rest on the back, with the shoulders raised and the knees flexed over a pillow, is essential; and although some amount of movement of the patient may be unavoidable, the less he is moved

or disturbed in any way the better; and the longer transport, if unavoidable, can be postponed the less harm is likely to result from it. Even the carrying in of the patient from the battlefield to the field ambulance is better postponed for several hours, if possible, and must be done with the greatest care and gentleness, by hand on a stretcher rather than in a wheeled vehicle. Nothing should be given by the mouth for at least thirty-six or forty-eight hours, and then only in small quantities. Thirst, which is always very distressing, may be relieved by rectal injections of warm water or saline solution, and only very occasionally may hot water in teaspoonful doses be allowed by the mouth. Severe shock must be met by strychnine hypodermically, and stimulants may be given per rectum. Feeding must be rectal at first, and considerable quantities of sterile normal saline or 5 per cent. glucose solution may be injected subcutaneously; in this way a considerable amount of liquid and of nutriment can be administered. The external wounds require cleansing and dressing in the usual way.

Whether morphine or opium in any form should be given depends very much upon the nature of the

case. If there is any probability of the question of operation having to be considered opium should not be given, as it masks the symptoms that would decide the necessity of operation and the time for operating. If, on the other hand, operation is out of the question, or has been definitely decided against, there is no reason for withholding opium or morphine. Many of these cases suffer acute pain, and opium gives them great relief. In cases obviously hopeless all that can be done is to alleviate their sufferings as far as possible by giving opium freely.

The question of operation has been much discussed, and all authorities are agreed that laparotomy in the field is justified only in exceptional circumstances. The ordinary rule of treatment in such cases under peace conditions would, of course, be to open the abdomen as soon as possible and repair the damage to the injured viscera. Experience has shown that this rule must be considerably modified in dealing with gunshot wounds under the conditions prevailing in the field.

Peritonitis does not necessarily follow a penetrating bullet wound of the abdomen, and a considerable proportion of the cases recover without operation.

An operation, to have the best ehanee of sueeess, must be done early, the earlier the better, and this means undertaking laparotomy in the field ambulanee, where all the objections to any operation in the field (*vide* ehap. II, p. 57) hold good, and in addition there are speeial reasons against operating on abdominal cases. Aseptie work is praetieally impossible, owing to the limited amount of assistanee available, the shortage of sterilised towels and dressings, the laek of water fit for use and the impossibility of sterilising it, and the diffieulties arising from wind, dust, flies, ete. These adverse eonditions render the performanee of laparotomy praetieally inadmissible; it adds a fresh risk to the patient's life from infeetion of the peritoneum, the very danger that the operation is undertaken to prevent.

The eases are often brought in after the most favourable time for operation has passed; it is not mueh use attempting to operate on them after seven hours, or at the most twelve hours, from the time of being wounded.

Sometimes at operations it has been found that the injuries were so extensive and numerous that it was praetieally impossible to do all that was re-

quired, especially in transverse or oblique wounds above the umbilicus.[1] At other times it was found that the perforations in the intestine were already sealed by adhesions, and these adhesions were broken down by the surgeon in searching for the damage.[2]

The necessity of moving the patients very soon after the operation is also a most serious drawback to the chances of a successful result.

In addition to the above difficulties, there is another objection of great weight to be considered. The very great pressure of work during and after an action means that to operate on even a few abdominal cases it would be necessary to leave untreated many others that require immediate surgical assistance, as so many of the small staff of the field ambulance would be occupied in the abdominal operations. It is not possible, nor would it be justifiable, to neglect cases that need attention and in whom the results of treatment would be satisfactory, in order to operate with very doubtful prospects of success on a comparatively small number, most of whom will probably not be benefited by the operation.

[1] Treves, *Med. Chir. Trans.*, vol. lxxxiii, p. 294.
[2] Treves, *loc. cit.*, p. 290.

For the above reasons the mortality following early laparotomy in the field has been very high, and both in South Africa and in Manchuria it was soon abandoned. Surgical opinion then swung to the other extreme, and it was said by many that no case of gunshot wound of the abdomen should be operated upon. The question is largely one of the circumstances under which the case has to be treated. It occasionally happens that a man is wounded within easy reach of a fixed hospital, where the surgical surroundings are satisfactory, that he is brought to hospital early, and that there is no great pressure of other work demanding immediate attention. In such a case, provided the condition of the patient is such that operation is not contra-indicated, there is no reason for departing from the recognised general rule. Some cases were operated on successfully in South Africa under such circumstances.[1] These must, however, always be exceptional.

There can be no doubt that in the field the right course is to treat penetrating gunshot wounds of the abdomen expectantly; operation is not justified when it offers little hope of recovery and adds

[1] *Report*, Case 36, p. 84, and Case 45, p. 86.

fresh danger to the patient's life. This conclusion has been amply confirmed by the experience of the Russians and the Japanese in Manchuria. To this general rule there are certain exceptions—

If wound of the intestine with extensive fouling of the peritoneum is evident from the first, for instance, if fæces are escaping from the external wounds, or a wounded coil of intestine has prolapsed, then it is clear that there is no hope from expectant treatment, and if the condition of the patient allows, and the surgical surroundings are satisfactory, operation should be undertaken at once.

Cases in which internal hæmorrhage is going on will certainly die if left alone, and operation may save some of them. Here also laparotomy must be done if the patient is not too weak, though in some few it will be found that in addition to the bleeding there are other injuries rendering the case hopeless.

Again, as the result of treating these cases expectantly, a considerable number will develop symptoms of commencing general peritonitis. The question of operation then arises again; they are hopeless if left alone, and possibly some of them may be saved by operation, which should therefore be undertaken if circumstances permit, and if the

condition of the patient does not altogether preclude any hope of recovery.

All these cases in which operation is justifiable are necessarily very unfavourable, but they are certain to die if left alone; and, indeed, it is only the fact that without operation they are hopeless, while operation holds out some chance, slender though it may be, of recovery, that justifies laparotomy in the field at all. This is, of course, an admission that abdominal surgery in the field has proved a failure. The reason is that it has been impossible, up to the present, and in all probability will always be impossible, to reproduce in the field the numerous conditions essential for the successful treatment of these very severe and dangerous injuries, according to modern surgical requirements.

When laparotomy is attempted, the difficulties met with are often great. There may be numerous perforations in the intestine, as many as twenty-eight have been recorded, and in addition there may be injuries to the mesentery and the omentum requiring repair, and wounds of the solid organs as well. When operation is done late, and peritonitis is already present, the gut may be softened so that sutures very readily cut out. In closing perfora-

tions in the intestine the line of suture should be across the axis of the gut, so that the infolding of the wall of the intestine does not narrow its lumen. Hæmorrhage must be arrested by ligature, or if from the solid organs, by suture or plugging. Portions of the intestine too severely damaged for suture, or deprived of their blood supply by wound of the mesentery, must be excised, and end-to-end anastomosis performed, preferably by simple suture. In commencing peritonitis, great care should be taken to avoid any rough handling of the intestine or any injury to the peritoneum. The abdomen should be flushed out with sterile water or normal saline at a temperature of 110° F., and some of the fluid left in. The addition of a drachm of 1 in 1,000 solution of adrenalin chloride to the fluid left in the abdomen checks any oozing and diminishes shock. Drainage is advisable in most cases, and in general peritonitis several small incisions should be made in such positions as to afford the best possible drainage of the peritoneal cavity. Rapidity in operating is of great importance; death from shock after prolonged operations is very probable. If the intestines are much distended, they must be emptied before closing the abdomen. Sometimes

the condition of the patient is so bad that all that can be done is to bring the wounded coil of intestine to the surface and establish an artificial anus, but this should always be avoided, if possible.[1]

Localised abscesses must be opened and drained, great care being taken not to break down any adhesions, owing to the danger of infecting the general peritoneal cavity.

Where the extra-peritoneal surface of the large intestine has been wounded, free external drainage is essential, and an attempt should be made to prevent or limit infection of the sub-peritoneal and intermuscular connective tissue. The wound must be enlarged, and the bowel brought to the skin and stitched there, or else a large drainage tube should be put into the bowel and the wound carefully packed round the tube, so as to allow fæces to escape without soiling the wound; or it may be possible to suture the wound in the wall of the bowel. Fæcal fistulæ generally form, but usually close without requiring further operation.

In gunshot wounds of the **stomach** the diagnosis depends on the course the bullet has taken, and

[1] *Report on Surgical Cases, South Africa*, Case 16, p. 81.

on the presence of vomiting and hæmatemesis. Escape of the contents of the stomach externally is extremely rare. Wound of the stomach is often accompanied by wound of the liver, and of the pleura and lung. The "explosive" effect occasionally produced when the full stomach is hit at a short range has already been mentioned. Most stomach wounds are simple perforations; sometimes slits of some length may be cut. The prognosis of perforations of the stomach by the small-bore bullet is not bad, owing to the small size of the aperture and the thickness of the stomach wall. The condition of the organ when wounded is of considerable importance; if empty, as it commonly is, the danger of peritonitis is much less. Wounds of the stomach are liable to be followed by sub-phrenic abscess, and later there may be adhesions causing pain after food, and pain on exertion or on taking a deep breath.

Wounds of the **rectum** are often accompanied by wound of the bladder, and by injuries to the pelvis and hip. Uncomplicated wounds of the rectum are not very fatal. The chief trouble is cellulitis from escape of fæces along the bullet track. Free drainage by the external wounds is necessary

in these cases. Colotomy is sometimes done to prevent the fæces reaching the wound. Another method, originally suggested by Dupuytren, is to divide the sphincters to allow of free escape of the fæces by the anus, so that they no longer find their way into the bullet track. This method has acted well in some cases, and as it is much less severe than colotomy, and requires a much less serious plastic operation afterwards, it is worthy of more extensive trial than it has yet had.[1]

Wound of the **liver** from the small-bore bullet is usually a narrow track, except in rare instances of wounds at very short ranges, when "explosive" effects may be produced. Larger missiles produce a larger track with more laceration. The prognosis in small-bore wounds is generally good, unless vessels large enough to cause fatal hæmorrhage are injured. In some cases of wound of the liver there is slight jaundice, which usually soon passes off. Bile sometimes escapes from the external wound, especially when the surface of the liver is grooved or scored by the bullet, and a biliary fistula may result. This usually closes spontaneously, but may persist for

[1] *Report on Surgical Cases, South Africa*, Case 99, p. 94.

a long time before closing. If bile is escaping it is important to ensure good drainage. Abscess of the liver sometimes follows a gunshot wound, and must be treated by incision and drainage in the usual manner. Such cases usually do well.

Wounds of the **spleen** are very seldom recognised, as most of them cause death from hæmorrhage in a short time, and the only symptom to which they give rise is hæmorrhage. The direction of the bullet's course is thc only other guide to a probable wound of the spleen. Bleeding from a bullet wound of the spleen does not necessarily go on to a fatal result; in one case in South Africa on operating there was an enormous quantity of blood in the peritoneum from a lacerated hole in the spleen, but the bleeding had ceased, and nothing was done to the splcen.[1] In another case the recent scar of a wound in the spleen was found in a patient who died from peritonitis a month after being wounded.[2] The treatment, if dangerous hæmorrhage is going on, is laparotomy and suture or plugging of the wound in the spleen; if that fails splenectomy must be performed.

[1] *Report*, Case 44, p. 86.
[2] Makins, *loc. cit.*, case 201, p. 463.

Gunshot wounds of the **pancreas** are very rarely seen. A bullet that wounds the pancreas must at the same time produce other injuries that are very likely to cause the injury to the pancreas to be overlooked, and in many cases death follows from wound of the great vessels. No case of wound of the pancreas was reported from South Africa. Injury to the pancreas causes no special symptoms that enable a diagnosis to be made, and the injury can only be discovered by searching for it in the course of an operation.[1] Unless specially looked for it is very liable to be overlooked. Of 12 cases of gunshot wound of the pancreas collected by von Mikulicz, 5 were operated on with 3 recoveries, and 7 that were not operated on all died.[2] The treatment necessary is to expose the pancreas by tearing through the gastro-hepatic omentum, arrest hæmorrhage by deep sutures, and drain the wound carefully to prevent the pancreatic secretion getting into the peritoneal cavity or the cellular tissues.[3]

Gunshot wounds of the **kidney** are very often complicated by other injuries; the kidney alone is

[1] Moynihan, *Abdominal Operations*, p. 715.
[2] *Annals of Surgery*, July, 1903.
[3] Moynihan, *loc. cit.*, p. 716.

seldom wounded except by bullets coursing obliquely through the loin. The injury is generally a clean perforation or a superficial groove. There is seldom any symptom except hæmaturia, which is usually slight, and lasts three or four days, sometimes longer. In some cases bleeding is more severe, but not dangerous. Clots may form in the ureter and cause severe pain of the usual kidney type, with retention of urine. If the pelvis of the kidney is wounded there will be extravasation of urine causing cellulitis or a peri-renal abscess. In uncomplicated punctures of the kidney no treatment is required except morphine if there is much pain. Cellulitis or an abscess requires incision and drainage, and may be followed by a urinary fistula. Early nephrectomy on account of hæmorrhage or great destruction of the kidney is never necessary; later, if the kidney is disorganised and a urinary fistula persists, nephrectomy may be required.

Wounds of the **bladder**, like those of other hollow organs, are usually perforations, and occasionally slits are cut by bullets striking tangentially. As in the stomach, "explosive" effects are seen, though rarely, when the full bladder is struck at a very short range. Intra-peritoneal puncture of the

bladder is not very serious; a small leakage of healthy urine into the peritoneum is not generally followed by dangerous peritonitis, and such cases often recover spontaneously. Where a long slit is cut in the surface of the bladder covered by peritoneum, laparotomy and suture may be required as for a ruptured bladder, but no case of this nature was reported from South Africa, owing to the conditions being unsuitable for the performance of any such operations. Extra-peritoneal wounds of the bladder are much more dangerous, as they cause extravasation of urine and severe cellulitis, and wounds of the base of the bladder are very often fatal from these conditions, and are often complicated by wound of the rectum and by long bullet tracks into the buttock or thigh, along which the urine may find its way. The treatment in all cases of wound of the bladder is to keep the bladder empty. For this purpose tying in a catheter often suffices, or if this is not satisfactory, the bladder may be opened above the pubes and drained by siphonage or by a Sprengel's pump. A simpler and probably more satisfactory method of drainage under field conditions is by means of a median perineal section. Extravasation of urine requires

immediate free incisions and drainage, and in cases of extensive cellulitis from extravasation continuous baths are often useful.

Two rather marvellous cases of lodgment of Mauser bullets in the bladder were reported from South Africa, the bullet being passed per urethram in one case; and being extracted from the urethra, where it was causing obstruction and retention of urine, in the other.[1]

In some cases bullets have passed through the chest and abdomen and caused very few symptoms, even when the bullet has traversed the whole length of the trunk. A few striking instances of these long bullet tracks may be quoted here.

(1) Entrance wound on the outer side of the left arm, through the deltoid; exit in the upper part of the left thigh, near the iliac crest.[2] The patient was lying down when hit, with his left arm thrown forward holding his rifle. Both wounds aseptic. Severe hæmoptysis for the first two days, the blood nearly choking him, afterwards only some uneasiness in the chest and difficulty of breathing. The bullet traversed the thorax, the diaphragm and the

[1] *Report*, Case 105, p. 96, and Case 114, p. 97.
[2] *Report on Surgical Cases, South Africa*, Case 63, p. 148.

lumbar region, apparently wounding no important organ except the lung. The patient was discharged fit for light duty on the twenty-eighth day.

(2) Bullet entered at the tubercle of the spine of the left scapula, and was extracted from the inner surface of the right thigh, two inches below Poupart's ligament, having passed obliquely through the trunk from above downwards, and from left to right. There were no serious symptoms.[1]

(3) Patient was hit from behind, at a range of eighty yards, while lying down firing. Entry two inches outside the left tuber ischii ; exit larger than entry, in fifth left intercostal space, half an inch inside the nipple. Patient was carried in an ambulance wagon for a week. No hæmoptysis at first, no hæmaturia or melæna. On admission to a general hospital on the twelfth day his temperature was 103·8°, and there was cough with blood-stained expectoration ; the respiration was short and quick, and the left side of the chest was tympanitic on percussion. The temperature became normal a week later, the symptoms cleared up, and he was up doing light hospital duty on the twentieth day.[2]

[1] *Report on Surgical Cases, South Africa,* Case 65, p. 148.
[2] *Ibid.*, Case 66, p. 148.

(4) Messrs. Bowlby and Wallaee report the ease of a man who, while lying down firing, felt his pipe break in his breeehes poeket. He put down his hand and found the broken pipe in his poeket, also a Mauser bullet, and finding blood on his hand it then oeeurred to him that he must have been wounded. The bullet had entered the left supra-seapular fossa, and after traversing the thorax and abdomen had emerged just below the left groin, and had then struek the pipe and lodged in the poeket. Not only was he unaware at the moment that he had been wounded, but the wounds healed without eausing any symptoms beyond a little stiffness in the lower part of the abdomen.[1]

Wounds of the External Genitals.—These are usually injuries of little importanee. In 124 eases reported from South Afriea, there were only two deaths. Wound of the urethra is the only injury of any importanee, and eomplete division of the urethra is uneommon ; it is generally notehed or partially divided, and as a rule there is no difficulty in passing a eatheter. Traumatie strieture of the urethra is a eommon result. The treatment is to pass a soft eatheter, and if possible suture the

[1] *A Civilian War Hospital*, pp. 152 and 257.

urethra over it. During the after-treatment extravasation of urine must be watched for, and treated by free incisions and drainage as soon as it appears. Later on plastic operations for urethral fistula may be necessary.

The penis is generally perforated, and sometimes there is a good deal of bleeding from wound of the corpora cavernosa. These wounds are not dangerous, and the only troublesome effect they give rise to is painful deformity on erection from contraction of the scar.

Wounds of the scrotum and testicles usually take the form of clean perforations. There is often bleeding into the loose scrotal tissues, and occasionally hæmatocele may occur. A considerable amount of pain and shock accompanies these injuries. The wounds usually heal without trouble. Castration is seldom required, except where the testicle is severely damaged by a large or irregular missile.

Wounds of the external genitals are often accompanied by wounds of the thigh, and injuries to the deep part of the urethra are frequently complicated by serious injury to the organs within the pelvis.

INDEX

6